2006 BIOSOLIDS QUALITY SUMMARY

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National Biosolids Partnership
CERTIFIED ENVIRONMENTAL MANAGEMENT SYSTEM

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EXECUTIVE SUMMARY

Biosolids are the nutrient-rich organic byproducts of the wastewater treatment process. Biosolids contain water, sand, organic matter, microorganisms, trace metals, and other chemicals. Because of their moisture content, humus-like characteristics, essential nutrients for plants, and very low levels of pollutants, biosolids are beneficial and safe to use as a soil conditioner, fertilizer for forest trees and agricultural crops, and as an ingredient of composts for landscaping.

This report summarizes the 2006 monitoring of biosolids from the West Point Treatment Plant (WPTP) and the South Treatment Plant (STP) at Renton. Both plants provide secondary wastewater treatment with anaerobic digestion of all solids followed by a dewatering process. The King County Wastewater Treatment Division (WTD) began recycling biosolids on land in 1973. The program has grown to beneficially recycle more than 110,000 wet tons annually in forestry, agriculture, soil reclamation and compost.

To ensure the safety of biosolids recycling, the physical, chemical, and microbial characteristics of biosolids are routinely monitored. This monitoring is performed monthly in order to characterize the biosolids, examine changes over time, and determine appropriate application rates for biosolids at reuse sites.

RESULTS OF 2006 MONITORING AND DATA ANALYSIS

Biosolids are regulated under both state and federal regulations (WAC 173-308 and 40 CFR Part 503). King County's biosolids meet quality standards for metals, pathogen reduction (Class B) and vector attraction reduction, which means they are safe for all land application projects.

Metals

Trend analyses of data collected from WPTP since 1981 and from STP since 1988 indicate that concentrations of most metals have declined. The concentrations of all regulated metals in biosolids from both treatment plants throughout 2006 fell below the most stringent state and federal regulatory levels labeled Very High Quality in Figures Ex-1 and Ex-2.

Comparisons of 2006 metals concentrations to 2005 concentrations yielded a statistical decrease in cadmium, calcium, and silver and a statistical increase in selenium in WPTP biosolids. Three metals (barium, boron, and silver) in STP biosolids were statistically lower, and five metals (cadmium, chromium, lead, manganese and nickel) were statistically higher in 2006 when compared to 2005 levels.

Conventional Constituents

In WPTP biosolids, total solids statistically increased in 2006. Phosphorus, potassium and pH were statistically lower in STP biosolids in 2006 than in 2005.

The fertilizer value of nitrogen in biosolids is measured as total nitrogen (the sum of organic nitrogen, ammonia, and nitrate-nitrite nitrogen). However, nitrate-nitrite nitrogen constitutes less than 0.01 percent in anaerobically digested biosolids and is disregarded in computations of fertilizer value. The average total nitrogen content of WPTP and STP biosolids in 2006 was about 5.8 and 7.0 percent, respectively, which was similar to 2005 levels.

Microbial Constituents

Analysis of all 2006 microbiological data for WPTP biosolids showed no significant difference from 2005 data. In STP biosolids, fecal coliform showed a significant increase in 2006.

Organic Constituents

While not required by federal or state biosolids regulations, King County's biosolids are analyzed for 135 trace organic compounds listed on the EPA Priority Pollutant List (40 CFR 423, Appendix A) and the Hazardous Substances List (40 CFR 116.4 A & B) as part of the National Pollutant Discharge Elimination System (NPDES) permit monitoring. Less than 13 percent of these compounds were detected in biosolids during 2006. Seventeen and twelve priority pollutants were detected at very low concentrations in WPTP and STP biosolids, respectively. These compounds included polynuclear aromatic hydrocarbons (PAHs), phthalates, polychlorinated biphenyls (PCBs), and solvents.

CONCLUSIONS

The 2006 data from WPTP and STP show that King County's biosolids quality is excellent when compared with all relevant criteria. Concentrations of regulated metals in biosolids were consistently below the most stringent state and federal standards for land application. Biosolids from both treatment plants may be used safely to improve soils and provide nutrients for agricultural crops and trees.

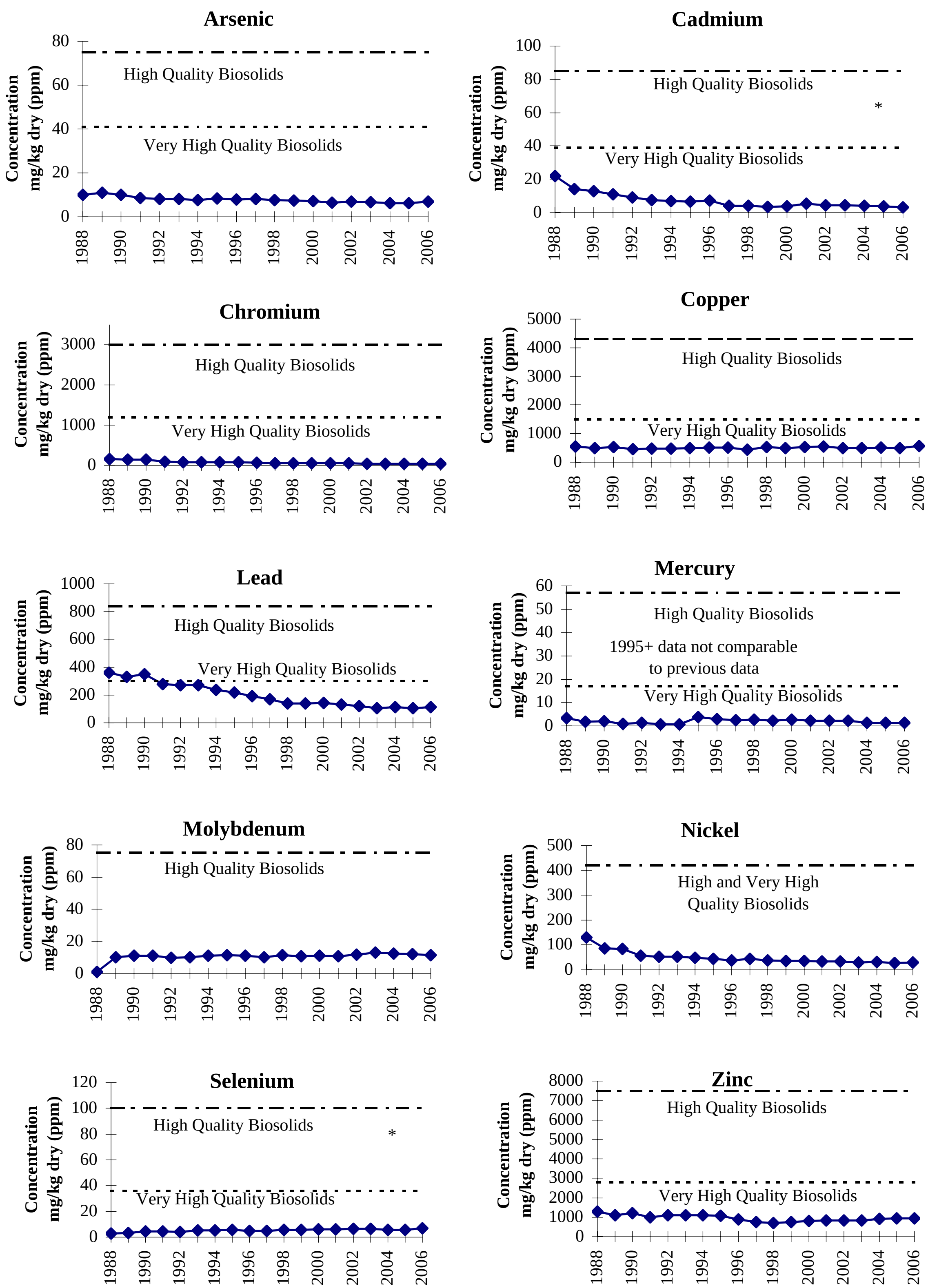

Figure Ex-1. Trends in Annual Average Concentrations of Metals in WPTP Biosolids

* indicates statistically significant increase or decrease by Mann-Whitney U test between 2006 and 2005 values.

Note: The WPTP was a primary treatment plant until 1996 when it was converted to full secondary treatment.

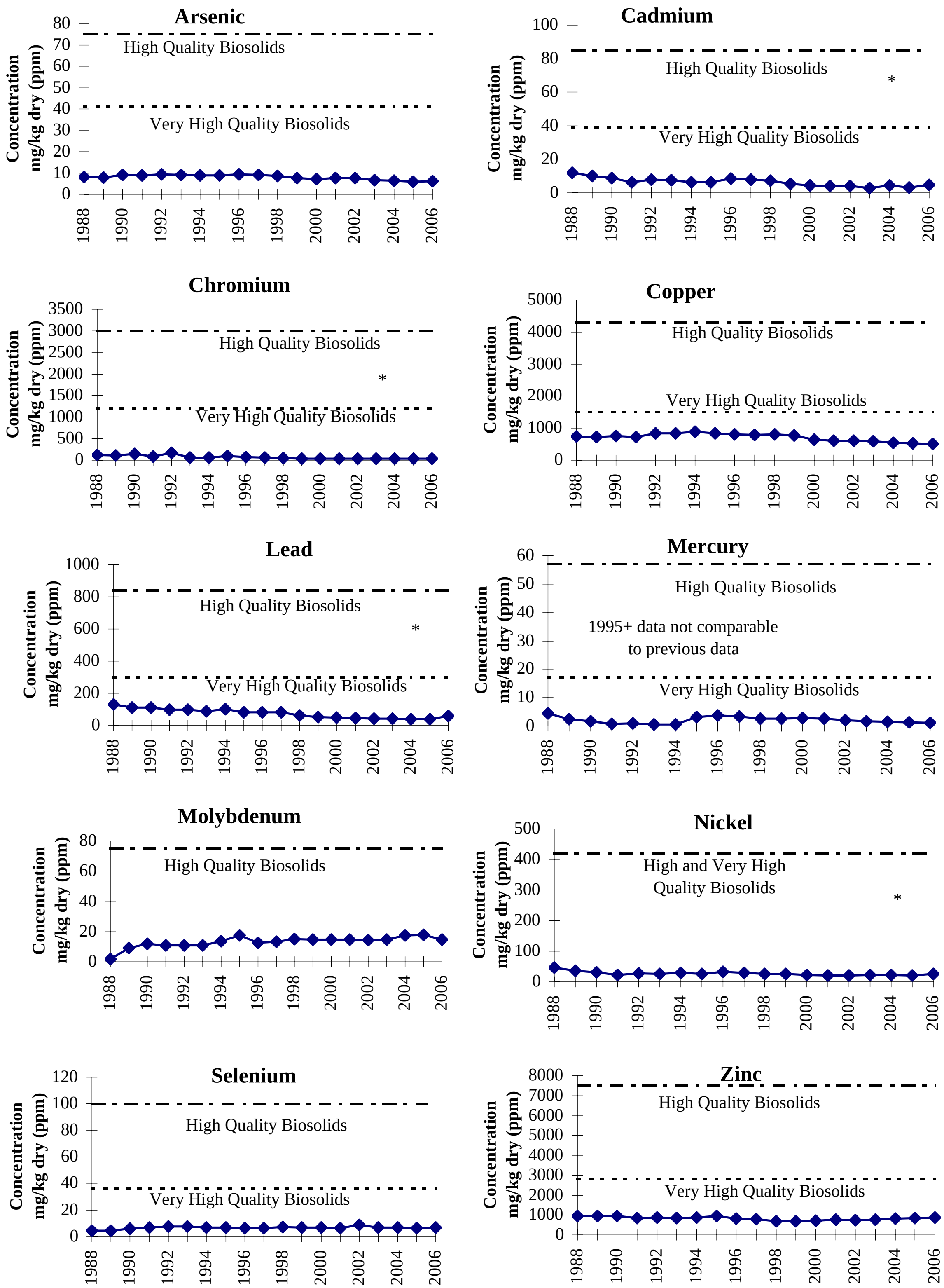

Figure Ex-2. Trends in Annual Average Concentrations of Metals in STP Biosolids

* indicates statistically significant increase or decrease by Mann-Whitney U test
between 2006 and 2005 values.

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APPENDIX

1.0 INTRODUCTION

Biosolids are a combination of water, sand, organic and inorganic particles, nutrients, microorganisms, trace metals, and chemicals. Biosolids are recycled as a fertilizer and soil amendment because they contain all essential micronutrients and significant amounts of macronutrients such as nitrogen, phosphorus, potassium, and sulfur, which plants need for growth and development. Their high organic matter content also aids in improving soil structure, moisture holding capacity and tilth.

The King County Biosolids Management Program (BMP) began recycling biosolids in 1973. Staff from the BMP, wastewater treatment plants, Hazardous Waste and Industrial Waste programs, Environmental Laboratory, and others collaborate to ensure that King County's biosolids continue to be as high in quality as is economically and practically achievable, safe, and used beneficially in a variety of projects. An integral part of this effort is the biosolids monitoring program which has included systematic sampling and analysis of biosolids since the early 1980s. The constituents routinely monitored include chemicals of health and environmental concern, industrial byproducts, microbes, and essential elements for plant and animal growth and development.

In 1993, the EPA implemented a federal rule, 40 CFR Part 503, in compliance with the Federal Clean Water Act, which set standards for the use of biosolids to protect public health and the environment. In 1998 the Washington State Department of Ecology (Ecology) implemented a new state biosolids rule (WAC 173-308) as part of the process to seek delegation for biosolids management from EPA. State and federal rules include operational standards, monitoring requirements, quality criteria and site management requirements.

Among the quality criteria set by state and federal standards are limits for concentrations of metals in biosolids. All biosolids applied to land must meet the ceiling limits for nine metals (Table 1, 40 CFR 503.13 and WAC 173-308-160). These limits are labeled in this report as "high quality biosolids." A more stringent "pollutant concentration limit" (Table 3 in 40 CFR 503.13 and WAC 173-308-160) is designated as "very high quality" in this report.

This report summarizes the 2006 monitoring of biosolids from the West Point Treatment Plant (WPTP) in Seattle and the South Treatment Plant (STP) in Renton. In 2006 biosolids were analyzed for the following constituents:

Conventionals including total solids, total volatile solids, pH, ammonia, organic nitrogen, total phosphorus, total potassium and total sulfur.

Microbes, including fecal coliforms, *Salmonellae*, enterococci, parasites and total viruses. (See Section 4 for a discussion of the microbial constituents.)

Metals and other elements including arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, barium, beryllium, boron, calcium, chromium, iron, magnesium, manganese, potassium, and silver (the first nine listed are regulated by Ecology and EPA).

Trace organics including volatiles, bases, neutrals, acids, pesticides, polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) from EPA's priority pollutant list (40 CFR 423, Appendix A) and Hazardous Substances List (40 CFR 116.4 A & B).

1.1 Wastewater Treatment Plant Processes

Both WPTP and STP utilize primary and secondary wastewater treatment in their process stream. Preliminary and primary treatment consists of screening, grit removal and gravitational settling. The primary effluent continues on to secondary treatment where microbial action and aeration remove more of the dissolved and suspended organic matter. Together, primary and secondary treatment removes 85 percent or more of the dissolved and suspended organic matter. The solids collected from both processes are directed to thickeners followed by mesophilic, anaerobic digestion where complex organic molecules are converted to methane, carbon dioxide, ammonia, water and other by-products. During digestion the volatile solids are reduced, which lowers the mass weight of total solids by almost half and homogenizes the biosolids. Bound to the organic matter are metals, additional microbes, and organic compounds. The organic matter is the source of conventional constituents including nitrogen, phosphorus, and sulfur. It is these compounds which make biosolids a valuable soil additive and source of nutrients for improved plant growth.

Although the two plants employ similar treatment processes they have differences which exist in the source of wastewater and composition of the conveyance system. South Plant influent is primarily from sanitary sewers from newer developments east of Lake Washington, whose dwellings have been equipped with copper piping. On the other hand, West Point receives wastewater from sanitary and storm sewers (a combined system), which results in large volumes of water surging into the plant during large rain events. These increased flows carry with it additional sediment along with contaminants from roads and other impervious surfaces. Furthermore, most of the sanitary flow to West Point originates from older Seattle neighborhoods which are plumbed with galvanized pipes (containing lead and iron). These differences help explain some of the biosolids quality variations seen between the two plants.

1.2 Pathogen Reduction and Stabilization

Under federal and state standards, King County’s biosolids from WPTP and STP are considered Class B biosolids, safe for all land application projects. EPA classifies biosolids as Class A or Class B based on the level of pathogen reduction. Additionally, biosolids must be stabilized for vector attraction reduction. To meet Class A standards, biosolids are treated to eliminate pathogens. Class B biosolids have been treated to reduce pathogens, but complete die-off occurs after land application. According to the EPA (1992), the “goal of the Class B requirements is to ensure that pathogens have been reduced to levels that are unlikely to pose a threat to public health and the environment under the specific use conditions." Several process alternatives are provided by the EPA to confirm that the required pathogen reduction and vector attraction reduction have been achieved.

Pathogen reduction of King County biosolids is accomplished by anaerobic digestion of wastewater solids. This is alternative 2 of 40 CFR 503 [503.32(b)(3)]. The solids are digested at mesophilic temperatures (95° to 98° F) for at least 15 days. WPTP and STP anaerobic digestion processes meet EPA criteria for a "Process to Significantly Reduce Pathogens" (PSRP), and qualify biosolids as Class B. At WPTP and STP, anaerobic digestion produces biosolids with microbial populations that are at least 90 percent lower than the populations in the raw solids entering the digesters. Any remaining pathogenic organisms die-off quickly after land application.

Vectors include "any living organisms capable of transmitting a pathogen from one organism to another..." (EPA 1992). According to the EPA, vectors for pathogens in biosolids would most likely include insects, rodents, and birds. One way to achieve vector attraction reduction is to reduce the amount of total volatile solids at least 38 percent during processing thus reducing odors that might attract vectors. The biosolids thus contain biodegradable material that decomposes so slowly that vectors are not attracted (EPA 1992). The volatile solids reduction is measured routinely at each treatment plant and is more than 50% at both WPTP and STP.

1.3 Continual Improvement

In July 2004, King County's Wastewater Treatment Division was certified into the National Biosolids Partnership's (NBP) Environmental Management System (EMS) for biosolids. King County is the third agency in the nation to achieve this certification following a rigorous, independent, third-party verification audit of its biosolids program. The EMS audit verified that King County, along with all of their biosolids partners, meets the requirements for certification and admittance to the NBP EMS program and is committed to excellence in biosolids management practices, goes beyond regulatory compliance obligations, and provides meaningful opportunities for public participation.

2.0 SAMPLING METHODOLOGY AND DATA ANALYSIS

WPTP and STP biosolids were monitored monthly for metals, conventional constituents and microbes. This frequency is twice the rate currently required by federal and state regulations. Organic compounds are monitored annually as required under our National Pollutant Discharge Elimination System (NPDES) permit.

2.1 Sampling Methodology and Sample Analysis

Biosolids samples are analyzed by the King County Environmental Laboratory and the WPTP and STP laboratories. Some analyses are performed by contract laboratories. Testing equipment and protocols at all laboratories comply with those recommended by EPA.

Samples of biosolids are collected monthly from WPTP and STP. The monthly sample from STP consists of grab samples taken every three hours and composited over a 24-hour period. The monthly sample from WPTP consists of grab samples collected every two hours during a 24-hour period; the subsamples are then combined and analyzed. Although collected in a single day, these combined samples reflect digester solids loading over an average of about 25 days at WPTP and 25 to 30 days at STP.

2.2 Data Analysis

Raw data for all constituents are presented in Appendix B. Relevant data are compared to state and federal regulatory limits (WAC 173-308-160 and 40 CFR Part 503.13, Tables 1 and 3) for high quality biosolids, State of Washington Dangerous Waste Criteria, and previously reported biosolids quality data from WPTP and STP. All data are stored and accessed on the King County Environmental Data Station (EDS) database.

2.3 Hypothesis Testing

Annual data are compared using statistical methods to evaluate year to year changes in biosolids quality. The selection of appropriate statistical tests for comparison strongly depended on the number of observations and their underlying distribution.

When a constituent was present in a sample in sufficient quantity to be detected with certainty by the laboratory analytical procedure, the detected concentration is reported. This is referred to as a "hit." When constituents were not present in a sample in sufficient concentration to be quantified (i.e., less than the method detection limit), the detection limit for the constituent is reported, which means the lowest concentration that can be detected. These data points are referred to as "undetecteds." Data sets that contain both hits and undetecteds are called "censored." There are several generally accepted ways to compute descriptive statistics for such data sets. The advice of Gilbert (1987) and of Helsel (1990) were followed in the treatment of censored data sets.

The underlying distribution refers to the shape of the frequency plot of all data for a particular constituent. The frequency distribution referred to as "normal" has a bell shape that is symmetrical about a central point, and is defined by a specific equation. Environmental data may follow this distribution, but often they follow others including skewed or bimodal frequency distributions.

With few exceptions, metals and conventional constituents such as nitrogen and potassium are always detected in biosolids. Some constituents show a reasonably normal distribution, but others do not. In order to compare data sets a single statistical procedure was chosen that was valid regardless of the distribution and the number of "hits." The most appropriate testing procedure that will yield valid results regardless of the distribution is the Mann-Whitney U test, also known as the Wilcoxon Rank Sum test. It permits the use of all data, including detection limits from censored data sets. It tests the hypothesis that the data sets represent two random samples from the same population regardless of the underlying distribution. If the test indicated a statistically significant difference (95% confidence or $p<0.05$) between data sets, it was concluded that they did not represent random samples from the same population.

Summary statistics including means and standard deviations are calculated for conventionals and metals. Since trace organic compounds are tested for twice per year, it is not possible to do statistical computations. Additionally, most trace organic compounds that are tested for are not detected. In lieu of statistics, the current year's values are compared to historical values for detected organic compounds.

Outlier analysis (using SPSS software application) is performed annually on metals data to identify outliers, or values that lie so far away from the rest of the data that they are likely not accurate measurements. If outliers cannot be explained by corresponding influent metal concentrations, known discharges or modeling, it is considered not representative of reality. Such values are reported, but excluded from the calculations of averages and statistics.

For microbiological data the geometric mean is used since the monthly values typically show variable results believed to be due to the irregular distribution of bacteria in a subsample. The geometric mean (GM) was calculated by using the following equation:

$$GM = [e^{(\Sigma \ln x_i /n)}]$$

Where: n = number of times a compound was detected
x_i = the ith value that was detected

Although called a mean, the geometric mean is an estimator of the median for populations with a log normal distribution, which is the distribution that most environmental data follows. For heavily skewed data sets, the median is a robust indicator of central tendency because its position is unaffected by very large or very small values. The median is that value above which 50 percent of the data are situated and below which 50 percent of the data are situated.

3.0 RESULTS AND CONCLUSIONS

Results of monitoring are given in tables in appendices of this report and include summary statistics, raw data, and charts. All data included in tables have been rounded in accordance with the accuracy of the particular analytical procedure used. Unless otherwise noted, all concentrations are reported on a dry weight basis. Concentrations of metals, conventionals, and organic compounds are reported in terms of parts per million (ppm or mg/kg) dry, and microbial concentrations are reported as number of organisms per gram dry and per 100 grams wet weight (Appendix B). This is the only exception to the reporting of results on a dry weight basis.

3.1 Conventional Constituents

Analytical results for WPTP and STP conventionals are shown in Tables A-1 and A-2 in Appendix A. The majority of these parameters are comparable to the 2005 WPTP and STP levels. Monthly values for all conventionals from each treatment plant are presented in Tables B-1 and B-2 in Appendix B.

3.1.1 Nitrogen

Total nitrogen (as measured by the Total Kjeldahl Nitrogen method) in biosolids has three components: readily available ammonia, which accounts for 15 to 20 percent of the total, bound organic nitrogen which accounts for most of the remainder, and nitrate-nitrite nitrogen which accounts for less than one one-hundredth of one percent (<0.01 percent) of the total. The ammonia and nitrate-nitrite fractions are associated with the water portion of the biosolids. Thus, the concentration of these constituents on a dry basis will likely drop with an increase in cake solids.

The average concentrations of organic and ammonia nitrogen are used to determine biosolids application rates. All the ammonia is immediately available for plant uptake, but may be lost by volatilization if biosolids are not incorporated into the soil. Of the bound organic nitrogen, 10 to 40 percent is mineralized and available for plant use during the first year after biosolids application. These are estimates that vary with the type of biosolids processing, site management practices such as incorporation into the soil, and weather or field conditions.

Average total nitrogen concentrations remained similar to the previous year. For WPTP biosolids, the 2006 average total nitrogen concentration was about 58,600 mg/kg dry, or about 5.8 percent. The 2006 average total nitrogen concentration for STP biosolids measured 69,500 mg/kg dry, or about 7.0 percent. These numbers were not significantly different from 2005 values.

3.1.2 pH

WPTP and STP biosolids showed 2006 average pH values of 8.90 and 8.50 units, respectively. STP's 2006 pH is statistically higher than in 2005.

3.1.3 Phosphorus and Potassium

The average total phosphorus concentration of WPTP biosolids (19,700 mg/kg dry) and the total potassium concentrations (1,700 mg/kg dry) were statistically unchanged when compared with the previous year. At STP phosphorus (24,200 mg/kg dry) and potassium (2,900 mg/kg dry) were significantly decreased from 2005 levels.

3.1.4 Sulfur

Sulfur, a plant-essential macronutrient, is present in biosolids as a constituent of organic compounds, in inorganic compounds that may include the sulfide, thiosulfate, and the sulfate (SO_4^{-2}) ions, and as elemental sulfur. One potential source of sulfate in biosolids is hydrocarbons that get washed into the collection system during rain events.

Organic sulfur compounds act as slow-release sources of sulfur as land-applied biosolids decompose. Sulfur is absorbed by plants primarily as the sulfate ion, although several sulfur containing amino acids may also be directly absorbed and metabolized. The 2006 average total sulfur content was 11,300 mg/kg dry and 10,500 mg/kg dry in WPTP and STP biosolids, respectively. These averages are both statistically similar to the previous year's averages.

3.1.5 Solids

The total solids (TS) content of biosolids is influenced by many factors, some of which include the proportion of primary solids mixed with waste activated sludge in the digester; the effectiveness of the digestion process at converting solids to gas and the dewatering process employed. Digestion, the process that follows thickening of primary and secondary sludges, breaks down organic compounds into gases, water, and a more stable organic matrix, and reduces the total solids. The final step in the production of biosolids is dewatering. Centrifuges dewater the biosolids with the addition of polymers.

The 2006 average percent TS (based on monthly samples) of WPTP biosolids was 26.7 percent and the 2006 average (based on monthly samples) for STP biosolids was 22.0 percent. TS at WPTP was statistically higher in 2006 than in the previous year. Daily samples are also analyzed to monitor treatment plant processes. TS values are used to convert wet weight lab results to a dry weight basis for uniform comparison to regulatory standards and to calculate biosolids application rates.

Volatile solids (VS) are that portion of the total solids that can be burned-off (volatilized) at 550^{o}C. These solids represent the easily decomposed, potentially putrescible organic material that could attract vectors. If this is reduced or minimized during digestion by at least 38 percent then vector attraction will likewise be reduced which is one of the criteria of producing good quality, Class B biosolids. The average VS concentration at WPTP in 2006 was 63%, and at STP the average VS concentration was 68%.

3.2 Metals

Monthly samples were analyzed for the presence and concentrations of 17 metals. Tables A-3 and A-4 in Appendix A present statistical summaries of the key metals concentrations from WPTP and STP biosolids during 2006. Tables B-3 and B-4 in Appendix B provide monthly values for all metals analyzed from WPTP and STP, respectively.

All metals concentrations in biosolids from WPTP and STP met federal criteria for land application. Cadmium and silver were statistically lower in 2006 than in 2005 in WPTP biosolids, and selenium was statistically higher (see Table A-3).

Three metals in STP biosolids (barium, boron and silver) were statistically lower, and five metals (cadmium, chromium, lead, manganese and nickel) were statistically higher in 2006 than their levels in 2005 (see Table A-4).

Outlier analysis identified four measures at WPTP as outliers (see section 2.3). In August, October and September, copper was higher than normal and selenium was high in June, though all measures were well below the most stringent regulatory limits. Measurements of copper in the influent at WPTP indicate that the elevated levels of copper in biosolids may be accurate, so those measures have been retained as valid. Selenium is measured in influent but is never found above the detection limit, and no probable reason could be determined for the June measurement, so it has been excluded from the calculation of averages and statistics.

Several unusually high outlier measurements were found at STP: cadmium in October, March and November; chromium in April; manganese in January and February; nickel in November; and lead in February, March, October and November. All of these metals except manganese are measured in the influent, and in each case, levels in the influent suggest that the levels measured in biosolids are accurate. Manganese is not measured in influent, and no reason for an increase could be determined for the January and February measures, so they have been excluded from calculations of averages and statistics.

3.2.1 Metals Trend Analyses

The 2006 data for each metal from WPTP and STP are presented in Appendix B, Tables B-3 and B-4. For most metals there is very little monthly variation during 2006. Most WPTP metals data are available since 1981, while STP metals data are available since 1988. Plots of annual average concentrations of key metals from 1988 to 2006 are presented in the Executive Summary and Appendices C and D.

Concentrations of silver in biosolids have continued to decline. Since 2000, mercury levels in King County biosolids have dropped by 50%, which is the direct result of a 2003 King County policy requiring dentists to install amalgam separators in their offices. Silver at STP has decreased 50% and at WPTP, it has decreased 59% since 2002. The reason for this decline is not clear, however the Washington Department of Ecology has put an emphasis on silver recovery from photography operations over the past few years. This, in combination with the increase in digital photography at the expense of film photography, and the increased usage of amalgam separators by dentists, is a likely reason for the decrease in silver.

The reduced concentrations of many metals in biosolids over the years are attributed to the ongoing corrosion control project implemented by the City of Seattle, to King County's Hazardous Waste Management and Industrial Waste Control and Pretreatment Program, and to the removal of lead from gasoline. Additionally the City of Renton started adding caustic to their water supply to reduce corrosion in 1999. This not only reduced corrosion from homes and businesses but also from the STP which used a considerable amount of city water as process water.

3.3 Trace Organic Compounds

The WPTP and STP biosolids were analyzed for 135 trace organic compounds (listed in Table A-7 in Appendix A). Prior to 1997, trace organic compounds were analyzed monthly. Very few compounds were ever detected and usually the same ones were seen from month to month with only minimal variation. Since 1997, testing has been conducted annually to meet NPDES permit requirements. EPA did not establish biosolids standards or monitoring requirements for organics due to low concentrations and minimal risk to public health and the environment. In general, research on the bioavailability of toxic organic compounds to plants indicates that the risk to humans consuming food crops grown on soils amended with biosolids is negligible. No adverse human acute or chronic toxicity effects have been reported resulting from ingestion of food plants grown in soils amended by biosolids (NRC, 1996).

In 2006, one composite sample from each plant were analyzed for the base-neutral extractables, pesticides, herbicides, PCBs, acid extractable fractions, and volatile organic compounds. The detectable organic compounds from WPTP and STP are summarized in Tables A-5 and A-6 in Appendix A, respectively. For comparison purposes the range of minimum and maximum 1996 values are included for each compound. Of the 135 organic compounds sought in 2006, only 17 were detected in WPTP biosolids and 12 were detected in STP biosolids. This represents about the same number of compounds for each plant as in 2005 samples.

The following types of organic compounds were detected in very low concentrations during 2005:

Polynuclear Aromatic Hydrocarbons (PAHs): components of fuel, asphalt, creosote, and products of combustion which are commonly found in the environment. Transfer of PAHs from soil has been shown to be minimal for root crops, and essentially zero for above-ground crops (NRC, 1996).

Phthalates, which are plasticizers used in many products including in food wrap, are prevalent in the environment. Phthalates do not persist in soils and are rapidly removed by volatilization and microbial decomposition (NRC, 1996).

Solvents, such as chlorobenzene, phenol, and 4-methylphenol, which are widely used as disinfectants.

PAHs and PCBs are two classes of trace organics that are of particular interest in determining dangerous or hazardous qualities of a solid waste residual, according to Ecology dangerous waste regulations (WAC 173-303-9903). The concentrations of the 7 PAH compounds detected in WPTP biosolids totaled 12.43 mg/kg dry in 2006. Three PAH compound were detected in STP biosolids with a total concentration of 3.80 mg/kg dry. The yearly totals continue to be well below Ecology's criterion of 10,000 mg/kg dry for total PAH compounds (WAC 173-303-100).

Three PCBs, Aroclor 1248, 1254 and 1260 were detected in WPTP biosolids in minute concentrations, while only one, Aroclor 1254 was detected in STP biosolids. The concentrations of all PCBs were well below the federal prescribed use guidelines of 10 mg/kg dry (40 CFR Part 761).

3.4 Microbiology

Results of microbiological analyses are summarized in Tables A-1 and A-2 in Appendix A. The levels of fecal coliform, *Salmonella* and enterococcus showed no statistical difference in 2006 when compared to 2005 levels in WPTP biosolids. Fecal coliform in STP biosolids showed a statistical increase in 2006. Viruses were detected once at both WPTP and STP during 2006 (See Appendix B, Tables B-1 and B-2 for monthly values, except viruses which are analyzed quarterly).

Additionally biosolids are tested quarterly for the presence of several parasites having public health significance. These include Ascaris, Coccidia, Giardia, Mite-ova, Nematodes, Taenia, Toxocara and Viable Helminth ova. None of these parasites were detected in WPTP or STP biosolids during 2006.

Fecal coliform, *Salmonellae*, and enterococci bacteria analyses are all performed by using the Most Probable Number (MPN) approach. This technique results in population counts that are reported as an MPN index. The index is an estimate based on probability formulas and a certain number of replicate tests from the same biosolids sample. Each replicate may give quite different results because of the irregular distribution of bacteria in the subsamples. The results of the test are compared to MPN tables, and the MPN index is assigned.

The MPN index is derived from a probability formula and statistics. Associated with each MPN index is a range called the 95% confidence interval. For example, an MPN index of 26 organisms/100 gram has a range of 9 to 78 organisms. This means that 95 percent of the replicates analyzed from a particular sample whose index is 26 will have bacterial counts that fall between 9 and 78 organisms/100 g, with a most probable number of 26 organisms/100 g. The important point to remember is that the MPN index is not a definite number, but rather the most probable number within a range of values.

3.5 Conclusions

Biosolids data from WPTP and STP for 2006 continue to show that King County's biosolids are of high quality when compared to all relevant criteria including prescribed use guidelines and the 2005 WPTP and STP biosolids quality data. Concentrations of most metals have leveled off or continue to decline in biosolids at both plants, and all metals for which there are regulatory criteria are detected in concentrations well below maximum allowable concentrations and below the more stringent 40 CFR Part 503.13 Table 3 limits.

WPTP and STP biosolids are very similar in terms of meeting the federal and state criteria. King County biosolids meet all Class B pathogen reduction standards under the federal regulation 40 CFR Part 503. As such, they are deemed safe for a variety of projects and applications including fertilization of food chain crops, forestlands, and general soil improvement. It is King County's continuing goal to achieve further improvements in biosolids quality.

4.0 MICROBIAL CONSTITUENTS OF BIOSOLIDS

Wastewater typically contains many millions of microorganisms per 100 ml. Some of these organisms are potentially disease producing, or pathogenic, to humans and other animals; others are harmless. One of the primary purposes of wastewater treatment is to significantly reduce or eliminate pathogenic microorganisms. The anaerobic digestion processes used to treat wastewater solids at King County's West Point Treatment Plant (WPTP) and South Treatment Plant (STP) reduce microbial concentrations from initial levels by up to 95 percent. Properly designed and managed land application programs ensure that proper field conditions exist for the elimination of any potentially remaining pathogens in biosolids, and thereby prevent them from entry into the food chain. In Washington, these conditions include warm, dry, sunny environments during at least part of the year.

The microorganisms in biosolids may be pathogenic or more commonly, indicators of pathogens. While laboratory analysis is not required to meet pathogen reduction standards, the King County Environmental Laboratory routinely analyzes biosolids for the presence of certain indicator microorganisms and pathogens. A brief description of each follows.

4.1 Fecal Coliform Bacteria

These microorganisms, most of which are nonpathogenic, are common to most warm-blooded animals, and include *Escherichia* and *Klebsiella* species. Their presence in high numbers in biosolids does not confirm the presence of pathogens, but suggests the possibility of pathogen presence. Fecal coliforms are the most widely accepted, though not the only indicator of fecal pollution.

4.2 Enterococcus Bacteria

These microorganisms, most of which are nonpathogenic, may have a slightly better survival rate than fecal coliform bacteria, and consequently are a good indicator of fecal pollution in surface waters. The group of organisms, under the genus Enterococcus, that are used as indicators are *E. faecalis, E. faecium, E. gallinarum* and *E. avium*. Similar to fecal coliform, the presence of these Enterococcus species do not confirm the presence of pathogens, but suggest the possibility of their presence.

4.3 *Salmonellae* Bacteria

This enteric pathogen is sometimes found in human or animal fecal matter. *Salmonellae* are associated with outbreaks of gastroenteritis and typhoid, human diseases usually contracted through consumption of contaminated drinking water or food.

Salmonellae survival in a forest or agricultural field is highly unlikely. Pathogenic microorganisms, including *Salmonellae* do not survive the warm, dry periods and the competition by naturally occurring organisms that all biosolids application sites experience (regardless of the time of year the biosolids are actually applied).

4.4 Total Enteric Viruses

Biosolids from WPTP and STP are routinely analyzed for enteroviruses including polioviruses, Coxsackie viruses, and ECHOviruses. Vaccine-strain polioviruses are commonly found in wastewater as a result of oral polio vaccine use. Viruses multiply only within living cells, so their numbers cannot increase in raw wastewater, wastewater solids, biosolids, or the environment. Processing of wastewater to biosolids further reduces the numbers to very low or undetectable levels.

4.5 Parasites

Parasites pose a potential risk to human health when present in biosolids due to the existence of resistant stages of the organisms and low infective doses. Ascaris ova are the most commonly isolated nematode ova and may be the most resistant of the ova or cysts found in biosolids. This makes them a good indicator of the presence of parasites as a group. Routine testing includes Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, viable Helmith ova and Toxocara. Samples are tested quarterly using a sedimentation and centrifugation technique.

5.0 PLANT-ESSENTIAL MICRONUTRIENTS AND MACRONUTRIENTS FOUND IN BIOSOLIDS

Two criteria must be satisfied in order to consider an element essential for plant life. First, an element is considered essential if a plant cannot complete its life cycle in the total absence of the element. Second, an element is considered essential if it forms part of any molecule or constituent of the plant that is itself essential (Epstein, 1972). Following these two criteria, 16 elements are considered essential to plant life. These are divided into two groups on the basis of the tissue concentrations observed in most plants. Macronutrients are essential elements found in plants in concentrations greater than or equal to 1,000 ppm dry weight basis (mg/kg dry). Micronutrients, also referred to as trace elements or minor elements, are found in tissue concentrations equal to or less than 100 ppm dry weight basis.

5.1 Macronutrients

Nine of the sixteen essential elements are considered macronutrients. Arranged in order from greatest to smallest concentration in plant tissue, these are: carbon, oxygen, hydrogen, nitrogen, potassium, calcium, magnesium, phosphorus, and sulfur.

Carbon, oxygen, hydrogen, nitrogen, phosphorus and sulfur are all constituents of amino acids and proteins including enzymes and coenzymes, as well as having other critical functions in plant cells. Potassium is essential as an activator of the enzymes involved in protein synthesis, and for translocation of anions such as NO_3^{-1} and SO_4^{-1}, from one plant part to another. Magnesium is a constituent of chlorophyll molecules and is responsible for the maximum rates of hundreds of enzymatic reactions involving adenosine triphosphate (ATP), for the ability of enzymes to fix CO_2 into organic molecules, and for protein synthesis in cells. Calcium functions to cement plant cell walls together, activates several enzymes, and is important in cell division.

5.2 Micronutrients

Seven elements are currently listed as micronutrients. These include, in descending order of concentration in dry plant tissue, chloride, iron, boron, manganese, zinc, copper, and molybdenum.

Some, but not all, plant species require other elements in micronutrient concentrations to complete their life cycles. These other elements include cobalt, sodium, silicon, selenium, and nickel. Higher animals whose nutritional requirements are obtained directly or indirectly from plants require additional elements in micronutrient concentrations. These include sodium, iodine, cobalt, selenium, nickel, silicon, chromium, tin, vanadium, and fluorine. These elements may be absorbed and stored by plants even though they are not strictly required for completion of their life cycle. Several other elements that may not be universally essential throughout the plant community, but that do contribute to increased growth of some crops, include strontium and barium (Sauchelli, 1969). Barium is another constituent of biosolids.

Biosolids are routinely analyzed for most of the above elements except iodine, fluorine and silicon. All elements listed above and for which King County currently tests are detected in biosolids.

Except for iron and sometimes manganese, plant essential micronutrients are usually found in low concentrations in soils, and their availability to plants is also low (Brady, 1990). Brady states, "... even though their (micronutrients) removal by plants is small, the cumulative effects of crop production over a period of years may rapidly reduce the limited quantities of these elements originally present in soils." Biosolids applications to heavily cropped agricultural fields can aid in the replenishment of micronutrients.

The following discussions summarize information from several sources on the importance of micronutrients, their functions in plant growth and development, and known antagonisms. Because biosolids contain all these nutrients, it can be thought of as "complete plant food," especially when compared with commercial fertilizers that focus on N-P-K analysis.

ELEMENT	**ESSENTIAL FUNCTION**	**CROPS HAVING A HIGH REQUIREMENT**
IRON	1. Essential component of the catalyst involved in the formation of chlorophyll, 2. Required for oxidation-reduction in respiration processes, 3. Constituent of certain enzymes and proteins.	blueberries, nut trees, cranberries, peaches, rhododendron, grapes
MANGANESE	1. Acts as a catalyst in several enzymatic and physiological reactions in plants, 2. Essential for nitrogen and inorganic acid metabolism, 3. Essential for carbon dioxide assimilation and breakdown of carbohydrates during photosynthesis, 4. Needed for the formation of carotene, riboflavin (vitamin B_2), and ascorbic acid (vitamin C).	beans, soybeans, onions, potatoes, citrus, dates
BORON	1. Essential for protein synthesis, nitrogen and carbohydrate metabolism, 2. Essential for root system development, fruit and seed formation, 3. Maintains correct water relations within plants.	alfalfa, clover, sugar beets, cauliflower, celery, apples, other fruits
ZINC	1. Essential for formulation of growth hormones (auxins), 2. Promotes protein synthesis, 3. Necessary for seed and grain maturation and production, 4. Catalyst for oxidation in plant cells and vital for transformation of carbohydrates, 5. Promotes the absorption of water and prevents stunting.	citrus and fruit trees, soybeans, corn, beans

MOLYBDENUM	1. Required for symbiotic nitrogen fixation and protein synthesis, 2. Required for the synthesis of ascorbic acid (vitamin C), 3. Makes iron physiologically available within plants, 4. Alleviates plant injury caused by the presence of excessive amounts of copper, boron, nickel, cobalt, manganese and zinc.	alfalfa, sweet clover, cauliflower, broccoli, celery
COPPER	1. Catalyst for respiration, 2. Required for chlorophyll synthesis, 3. Required for carbohydrate and protein metabolism, 4. Enzyme constituent. Copper has also been used as a fungicide for more than 100 years to control wheat blunt and smut. Certain compounds of copper are still used in organic farming as pesticides.	citrus and fruit trees, onions, small grains
CHLORIDE	1. Role is unclear but it enhances root and top growth of plants, especially when young, 2. Stimulates photosynthesis.	tomatoes, cotton, buckwheat, barley, lettuce, sugar beets, cabbage, carrots, corn, potatoes
SODIUM	1. Improves plant vigor, helps resist disease, 2. Improves the keeping quality of many crops, 3. Imparts color and flavor to vegetable crops, 4. Can substitute for up to 50% of the potassium required by some plants.	celery, sugar beets, Swiss chard, turnips, table beets
COBALT	1. Essential for microorganisms involved with the symbiotic fixation of nitrogen in root nodules of legumes, 2. Constituent of vitamin B_{12} (required by animals, but not by plants).	all legumes, cotton, mustard
VANADIUM	1. May function in biological oxidation-reduction reactions, 2. May substitute for some molybdenum requirement.	asparagus, rice, lettuce, barley, corn
CHROMIUM	Required by higher animals and functions in the action of insulin on cell membranes.	

Known Antagonisms Between Macro and Micronutrients: (from Brady, 1990)

1. Excess copper or sulfate may adversely affect the utilization of molybdenum.
2. Iron deficiency is encouraged by an excess of zinc, manganese, copper, or molybdenum.
3. Excess phosphate may encourage a deficiency of zinc, iron, or copper, but enhances the adsorption of molybdenum.
4. Heavy nitrogen fertilization intensifies copper and zinc deficiencies.
5. Excess sodium or potassium may adversely affect manganese uptake.
6. Excess lime reduces boron uptake.
7. Excess iron, copper, or zinc may reduce the adsorption of manganese.

6.0 GLOSSARY

anaerobic digestion: the decomposition of organic matter without the presence of oxygen. Anaerobic digestion of sewage takes place in tanks where 40 to 60 percent of the volatile solids are decomposed by anaerobic bacteria and converted to methane and carbon dioxide. Anaerobic digestion also typically reduces viruses and pathogenic bacterial populations by 90 percent or more. (See also: mesophilic, pretreatment, primary treatment, secondary treatment, tertiary treatment)

available nutrient: that portion of any naturally occurring or fertilizer-borne element or compound in the soil that can be readily absorbed and assimilated by growing plants. (See also: macronutrient, micronutrient)

background level: amounts of nutrients, organisms, or pollutants already existing in the environment before biosolids applications.

bacteria: single-celled microorganisms that lack chlorophyll. Some bacteria are capable of causing human, animal or plant diseases; others are essential for the decomposition of organic matter in soils, in secondary wastewater treatment (see definition below), and in digestive processes in animals. (See also: pathogenic microbe, virus)

biosolids: (Water Environment Federation definition) - "primarily organic product produced from the wastewater treatment plant process, that can be beneficially recycled". It contains water, sand, organic matter, microorganisms, trace metals and other chemicals. (See also: Class A Biosolids, Class B Biosolids, exceptional quality biosolids)

ceiling limit (or concentration): refers to federal regulation 40 CFR Part 503.13 (EPA, 1992) Table 1 concentrations of metals in biosolids. The ceiling limit is the maximum concentration of a metal allowed in biosolids in order to be considered exceptional quality and safe for land application. (See also: exceptional quality biosolids, pollutant concentration)

Class A Biosolids: the EPA designation for high quality biosolids that have been treated to reduce pathogens to below detectable levels. Federal regulations require this level of quality for biosolids that are sold or given away in a bag or other container, or applied to lawns or home gardens. (See also: biosolids, Class B Biosolids, exceptional quality biosolids)

Class B Biosolids: the EPA designation for high quality biosolids that have been treated to significantly reduce pathogens to levels that are safe for beneficial use in land application. Federal regulations require site management and access restrictions when biosolids of this quality are land applied, including sites with high potential for public contact. (See also: biosolids, Class A Biosolids, exceptional quality biosolids)

dewatering: any of several processes used to remove water from biosolids in order to reduce its volume prior to recycling. These processes may include evaporation, passage through belt filter presses which squeeze water out of biosolids, or centrifuging which drives water out by spinning, much as water is driven out of clothes during the "spin" cycle of a clothes washing machine.

essential element: an element that is required by all organisms in order to complete their life cycles. (See also: macronutrient, micronutrient, heavy metal, trace metal, available nutrient)

exceptional quality biosolids: common terminology referring to biosolids whose metals concentrations do not exceed standards of federal regulation 40 CFR Part 503.13 (EPA, 1992) Table 1 and Table 3. Exceptional quality biosolids must meet one of the Class A pathogen requirements and one of the vector attraction reduction options. (See also: Class A biosolids, pollutant concentration)

hazardous waste: any material that according to EPA criteria on ignitability, corrosivity, reactivity, or TCLP is a potential hazard to human health and the environment if not properly controlled. (See also TCLP)

heavy metal: metallic elements whose densities are equal to or greater than 5.0 g/cm^3 including, but not limited to chromium, lead, zinc, copper, cadmium, mercury, nickel, silver, and iron. Some heavy metals are required in trace concentrations for all animal and plant life. These include manganese, iron, copper, zinc, and molybdenum. Others like cadmium, mercury, and lead can be toxic to living organisms. Still others have no known effects on living organisms. (See also: micronutrient, trace metal)

mg/kg: milligram per kilogram; equivalent to a part per million.

macronutrient: an essential element needed in large amounts by a plant or animal in order to complete its life cycle. Macronutrients are found in dry tissue in concentrations greater than 1,000 ppm. Plant macronutrients include nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, carbon, hydrogen and oxygen. (See also: micronutrient, trace metal)

mesophilic digestion: One of two optimum temperature ranges (85-100^oF which equates to 30-38^oC) that increases the rate of anaerobic digestion to maximize efficiency and minimize solids retention times. (See also: anaerobic digestion, primary treatment, secondary treatment)

micronutrient: (also called trace element) an essential element needed in extremely small amounts by a plant or animal in order to complete its life cycle. Micronutrients are found in dry tissue in concentrations less than 100 ppm. Plant micronutrients include iron, boron, manganese, zinc, copper, chloride, cobalt, and molybdenum. Micronutrients are often depleted or unavailable in soils that have been cropped continuously and that have received only applications of nitrogen fertilizers. (See also: macronutrient, trace metal)

pathogenic microbe: any microorganism that has the potential to cause disease. These may include certain bacteria, fungi, and viruses. (See also: bacteria, virus)

"pollutant concentration" (or limit): refers to the 40 CFR Part 503.13 (EPA, 1992) Table 3 concentrations of metals in biosolids. Municipalities whose biosolids meet this limit are exempt from certain recordkeeping and reporting requirements. (See also: exceptional quality biosolids)

pretreatment: the removal of certain pollutants from industrial waste before discharging it to the wastewater treatment system. Pretreatment is required of industries whose wastes fail to comply with local or federal pretreatment standards. This may necessitate the installation of special equipment for pollutant removal. (See also: primary treatment, secondary treatment, tertiary treatment)

primary treatment: the first phase of wastewater treatment in which solids are removed through gravitational settling. (See also: pretreatment, secondary treatment, tertiary treatment)

priority pollutants: a group of chemicals specifically listed in the Code of Federal Regulations (40 CFR 423, Appendix A) given priority for regulatory control.

secondary treatment: the second phase of wastewater treatment that uses aeration and the biological action of bacteria to remove 95 percent or more of the dissolved and suspended organic matter remaining in wastewater after primary treatment. (See also: pretreatment, primary treatment, tertiary treatment)

tertiary treatment: a third phase of wastewater treatment in which most of the remaining pollutants are removed from effluent following secondary treatment. The processes used include among others, sand filtration and ultraviolet light disinfection. (See also: pretreatment, primary treatment, secondary treatment)

tilth: the physical condition of a soil as related to its ease of tillage, fitness as a seedbed, and its impedance to seedling emergence and root penetration.

trace metal: any metallic element detected in biosolids in extremely low concentrations (equal to or less than 100 ppm). The term is also commonly used as a synonym for micronutrient, although not all micronutrients are metals. (See also: essential element, heavy metal, macronutrient, micronutrient)

trace organic: any organic compound detected in biosolids in extremely low concentrations, usually several parts per million (mg/kg) or less.

virus: the smallest of the microorganisms, these are obligate parasites composed of a nucleic acid (RNA or DNA) core and a protein coat. They cannot grow or reproduce outside a host organism. (See also: pathogenic microbe, bacteria)

wastewater: water that has been previously used in homes, businesses or industry and requires treatment before it can be discharged to surface waters (i.e., Puget Sound) or reused.

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APPENDIX A

SUMMARY TABLES OF ALL PARAMETERS

TABLE A-1. 2006 Summary of Conventional and Microbiological Data for West Point Biosolids

CONVENTIONAL	2006 Mean	2006 Standard Deviation	2006 No. of times Detected	2006 Minimum	2006 Median	2006 Maximum	2005 Mean
Total Solids *(i)* (% of wet)	26.7	1.89	12	23.8	26.7	30.0	24.9
Total Volatile Solids (% of wet)	63.3	5.19	12	54.3	65	70.3	64
pH (std. units)	8.90	0.17	12	8.45	8.95	9.09	8.90
Ammonia Nitrogen (mg/kg dry)	8,500	1,550	12	5,850	8,830	10,500	9,700
Organic Nitrogen (mg/kg dry)	50,100	9,100	12	33,300	52,000	62,800	51,400
Total Phosphorus (mg/kg dry)	19,700	3,120	12	13,700	19,800	25,400	21,000
Total Potassium (mg/kg dry)	1,700	220	12	1,400	1,700	2,000	1,600
Total Sulfur (mg/kg dry)	11,300	1,036	12	9,550	11,500	12,700	11,080

MICROBIOLOGICAL	2006 Median	2006 Minimum	2006 Maximum	2006 No. of times Detected		2006 Geometric Mean	2005 Geometric Mean
Fecal Coliform (org/g dry)	58,000	18,000	560,000	12		68,000	39,000
Enterococcus (org/g dry)	175,000	58,000	510,000	12		169,000	245,000
Salmonella (org/4g dry)	0.63	0.27	78	9		0.96	0.34
Total Enteric Viruses (PFU/4g dry)	0.32	<0.28	<0.31	1		<0.32	<0.32
Parasites (no units)	NF	-	-	NF		-	NF

Note: Test of Statistical Significance indicates a significant increase (i) or decrease (d) between the 2005 and 2006 values at P <0.06 based on Mann-Whitney U test.
ND = not detected CC = cannot be calculated PFU= Plaque forming unit NF= none found
Total Enteric Viruses include: polioviruses, Coxsackie viruses and ECHOviruses.
Parasites include: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, viable Helmith ova and Toxocara.

TABLE A-2. 2006 Summary of Conventional and Microbiological Data for South Plant Biosolids

CONVENTIONAL	2006 Mean	2006 Standard Deviation	2006 No. of times Detected	2006 Minimum	2006 Median	2006 Maximum	2005 Mean
Total Solids (% of wet)	22	0.82	12	20	22.3	22.8	21.7
Total Volatile Solids (% of wet)	67.9	1.53	12	65	68.4	70	68
pH *(d)* (std. units)	8.5	0.11	11	8.3	8.5	8.6	8.61
Ammonia Nitrogen (mg/kg dry)	12,200	1,760	12	9,700	12,400	15,700	12,700
Organic Nitrogen (mg/kg dry)	57,300	9,070	12	48,200	54,900	83,600	60,400
Total Phosphorus *(d)* (mg/kg dry)	24,200	3,410	12	16,000	24,500	28,600	33,400
Total Potassium *(d)* (mg/kg dry)	2,600	250	12	2,200	2,600	3,100	2,900
Total Sulfur (mg/kg dry)	10,500	760	12	9,390	10,800	11,500	10,400

MICROBIOLOGICAL	2006 Median	2006 Minimum	2006 Maximum	2006 No. of times Detected		2006 Geometric Mean	2005 Geometric Mean
Fecal Coliform *(i)* (org/g dry)	61,000	22,000	640,000	12		74,200	28,000
Enterococcus (org/g dry)	300,000	130,000	2,300,000	12		358,100	300,000
Salmonella (org/4g dry)	0.39	<0.35	2.02	5		0.52	2
Total Viruses (PFU/4g dry)	0.37	<0.36	0.37	1		<0.37	<0.38
Parasites (no units)	NF	-	-	NF		-	NF

Note: Test of Statistical Significance indicates a significant increase (i) or decrease (d) between the 2005 and 2006 values at P <0.06 based on Mann-Whitney U test.

ND = not detected CC = cannot be calculated PFU= Plaque forming unit NF= none found

Total Enteric Viruses include: polioviruses, Coxsackie viruses and ECHOviruses.

Parasites include: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, viable Helmith ova and Toxocara.

TABLE A-3. 2006 Summary of Metals Data for West Point Biosolids								
METALS (mg/kg dry)								
	2006 Mean	Standard Deviation	Minimum	2006 Median	Maximum	2005 Mean	40 CFR 503 Regulatory Limits *	No. of Times Detected
Arsenic	6.95	1.05	5.48	6.94	8.53	6.2	41	12
Barium	252	20	226	254	291	251		12
Beryllium	<0.20	0.01	<0.18	<0.20	0.23	<0.21		5
Boron	15.2	1.1	13	15	17	14.9		12
Cadmium *(d)*	3.03	0.23	2.7	3.04	3.58	3.64	39	12
Chromium	39.7	6.7	31.1	38.3	49.7	36.5		12
Copper	561	117	407	563	736	500	1,500	12
Iron	17,700	3,560	12,900	16,800	23,400	16,700		12
Lead	111	17.5	91	105	136	107	300	12
Magnesium	6,390	470	5,340	6,540	7,030	5,960		12
Manganese	714	393	261	700	1,230	588		12
Mercury	1.43	0.59	0.97	1.25	3.13	1.38	17	12
Molybdenum	11.5	2.23	8.63	11.8	15.3	11.9	*	12
Nickel	30.4	5	24.1	29	37.4	28	420	12
Selenium *(i)*	6.86	0.85	5.7	6.7	8.7	5.84	100	12
Silver *(d)*	20.3	2.6	16	21	24.9	23.8		12
Zinc	940	91	818	930	1090	940	2,800	12

Note: Test of Statistical Significance: indicates a significant increase (i) or decrease (d) between the 2005 and 2006 values at P <0.05 based on Mann -Whitney U test.

Note: means and standard deviations are computed on the basis of the twelve monthly samples for 2006, excluding outliers.
Minima, medians, and maxima are determined on the basis of all data collected during the monitoring year, excluding outliers.

< = less than method detection limit. The detection limit may vary depending on the analytical method used.

* 40 CFR 503 Limit for Very High Quality (Table 3) is under reconsideration.

TABLE A-4. 2006 Summary of Metals Data for South Plant Biosolids								
METALS (mg/kg dry)								
	2006 Mean	Standard Deviation	Minimum	2006 Median	Maximum	2005 Mean	40 CFR 503 Regulatory Limits **	No. of Times Detected
Arsenic	6.16	0.76	5	5.97	7.76	6.01	41	12
Barium *(d)*	216	15.9	198	211	243	231		12
Beryllium	<0.23	0.02	<0.22	<0.23	<0.26	<0.23		1
Boron *(d)*	13	0.7	11.8	13.3	14.4	14		12
Cadmium *(i)*	4.75	1.62	2.8	4.47	7.2	3.13	39	12
Chromium *(i)*	41.4	7.3	28.7	41.9	54.4	33.4		12
Copper	507	38	461	498	584	531	1,500	12
Iron	19,000	2,620	15,800	19,000	24,600	17,600		12
Lead *(i)*	59.6	17	38.6	60.2	93	40.6	300	12
Magnesium	9,060	1,305	7,120	9,370	10,700	10,120		12
Manganese *(i)*	480	90	380	470	700	380		12
Mercury	1.1	0.28	0.88	1	1.84	1.29	17	12
Molybdenum	14.6	2.47	11.6	14.3	19	17.9	**	12
Nickel *(i)*	26.4	4.28	20	25.2	35.9	21.4	420	12
Selenium	6.95	0.86	6.1	6.75	9.24	6.42	100	12
Silver *(d)*	12.1	0.76	10.7	12.3	13.6	14.9		12
Zinc	866	124	690	875	1040	849	2,800	12

Note: Test of Statistical Significance: indicates a significant increase (i) or decrease (d) between the 2005 and 2006 values at P <0.05 based on Mann-Whitney U test.
Note: means and standard deviations are computed on the basis of the twelve monthly averages for 2006, excluding outliers.
Minima, medians, and maxima are determined on the basis of all data collected during the monitoring year, excluding outliers.
< = less than method detection limit. The detection limit may vary depending on the analytical method used.

** 40CFR 503 Limit for Very High Quality (Table 3) is under reconsideration

TABLE A-5. 2006 Organic Compound Data for South Plant Biosolids

		Acids (mg/kg dry)		Volatiles (mg/kg dry)			
Sample Number	Date	Phenol		Acetone	2-Butanone (MEK)	4-Methyl-2-Pentanone (MIBK)	Toluene
L40296-2	18-Sep-06	242.0		4.59	2.62	0.12	0.133
	1996 Min - max	*10.9-12.0*		*0.440-3.71*	*0.180-3.08*	*ND*	*0.051-0.139*

		Volatiles (cont.)		Neutrals/PAHs (mg/kg dry)			
Sample Number	Date	Ethybenzene	Total Xylenes	Bis(2-Ethyl-hexyl)Phthalate	Fluoranthene*	Phenathrene*	Pyrene *
L40296-2	18-Sep-06	0.036	0.167	152	1.1	1.34	1.36
	1996 Min - max	*0.028-0.251*	*0.024-1.433*	*46-156*	*1.5-4.93*	*1.57-6.35*	*2.11-6.49*

	PCBs (mg/kg dry)
	Aroclor 1254
Geomentric mean of montly samples	<0.19[g]
1996 Min - max	*0.176 - 0.635*

* indicates Polynuclear Aromatic Hydrocarbons (PAH) compound

ND = no data available or the compound was not detected.

1996 Min - max = Minimum and maximum detected values for 1996 trace organic compounds to use as comparison for 2006 data.
In 2006 one sample was analyzed for all 135 organic compounds, as compared to 1996 when monthly samples were analyzed.
g = geometric mean, monthly samples were analyzed in 2006 for some Polychlorinated Biphenyls (PCBs).

TABLE A-6. 2006 Organic Compound Data for West Point Biosolids

		Acids (mg/kg dry)	Volatiles (mg/kg dry)		
Sample Number	Date	Phenol	Acetone	Toluene	2-Butanone (MEK)
L40296-1	18-Sep-06	17.50	6.51	0.072	2.13
	1996 Min - max	*10.9 - 12*	*0.440 - 3.71*	*0.051 - 0.139*	*0.180 - 3.08*

		Neutrals/PAHs (mg/kg dry)						
Sample Number	Date	Anthracene *	Benzo(A) Anthracene *	Bis(2-Ethyl-hexyl)Phthalate	Chrysene *	Fluoranthene *	Phenanthrene *	Pyrene *
L40296-1	18-Sep-06	1.00	0.98	134	1.27	2.45	3.44	3.29
	1996 Min - max	*0.71 - 0.83*	*0.77 - 2.37*	*46 - 156*	*0.79 - 3.33*	*1.5 - 4.93*	*1.57 - 6.35*	*2.11 - 6.49*

Sample Number	Date	1,4 Dichloro-benzene	2-Methyl-naphthalene	4,4' DDE
L40296-1	18-Sep-06	4.90		
	1996 Min - max	*0.42*	*ND*	*0.031 - 0.041*

	PCBs and Pesticides (mg/kg dry)		
	Aroclor 1248	Aroclor 1254	Aroclor 1260
Geometric mean of monthly samples	<0.021[g]	<0.040[g]	<0.018[g]
1996 Min - max	*0.32*	*0.176 - 0.635*	*0.149 - 0.310*

ND = no data available or the compound was not detected.

* indicates Polynuclear Aromatic Hydrocarbon (PAH) compound

In 2006 one sample was analyzed for all 135 organic compounds, as compared to 1996 when monthly samples were analyzed.
g = geometric mean, monthly samples were analyzed in 2006 for some Polychlorinated Biphenyls (PCBs).

Table A-7. List of Organic Compounds Analyzed in King County Biosolids

Pesticides and PCBs	Volatiles	Bases/Neutrals/Acids	
4,4-DDE	1,1-Dichloroethane	1,2-Dichlorobenzene	Benzyl Alcohol
4,4-DDD	1,1-Dichloroethylene	1,2-Diphenylhydrazine	Bis(2-chloroethoxy)methane
4,4-DDT	1,2-Dichloroethane	1,3-Dichlorobenzene	Bis(2-chloroethyl)ether
Aldrin	1,2-Dichloropropane	1,4-Dichlorobenzene	Bis(2-chloroisopropyl)ether
Alpha-BHC	1,2-Trans-Dichloroethylene	1,2,4-Trichlorobenzene	Bis(2-ethylhexyl)phthalate
Arochlor-1016 †	1,1,1-Trichloroethane	2-Chloronaphthalene	Butyl Benzyl Phthalate
Arochlor-1221 †	1,1,2-Trichloroethane	2-Chlorophenol	Carbazole
Arochlor-1232 †	1,1,2-Trichloroethylene	2-Methylnaphthalene	Chrysene *
Arochlor-1242 †	1,1,2,2-Tetrachloroethane	2-Methylphenol	Di-n-Butyl Phthalate
Arochlor-1248 †	2-Butanone (MEK)	2-Nitroaniline	Di-n-Octyl Phthalate
Arochlor-1254 †	2-Chloroethylvinyl Ether	2-Nitrophenol	Dibenzo(a,h)anthracene *
Arochlor-1260 †	2-Hexanone	2,4-Dichlorophenol	Dibenzofuran
Beta-BHC	4-Methyl-2-Pentanone (MIBK)	2,4-Dimethylphenol	Diethyl Phthalate
Chlordane	Acetone	2,4-Dinitrophenol	Dimethyl Phthalate
Delta-BHC	Acrolein	2,4-Dinitrotoluene	Fluoranthene *
Dieldrin	Acrylonitrile	2,6-Dinitrotoluene	Fluorene *
Endosulfan 1	Benzene	2,4,5-Trichlorophenol	Hexachlorobenzene
Endosulfan Sulfate	Bromodichloromethane	2,4,6-Trichlorophenol	Hexachlorobutadiene
Endosulfan11	Bromoform	3-Nitroaniline	Hexachlorocyclopentadiene
Endrin	Bromomethane	3,3-Dichlorobenzidine	Hexachloroethane
Endrin Aldehyde	Carbon Tetrachloride	4-Bromophenyl Phenyl Ether	Indeno(1,2,3-c,d)pyrene *
Gamma-BHC	Chlorobenzene	4-chloro-3-methylphenol	Isophorone
Heptachlor	Chlorodibromoethane	4-Chloroaniline	N-Nitroso-di-n-propylamine
Heptachlor Epoxide	Chloroethane	4-Chlorophenyl Phenyl Ester	N-Nitrosodimethylamine
Methoxychlor	Chloroform	4-Methylphenol	N-Nitrosodiphenylamine
Toxaphene	Chloromethane	4-Nitroaniline	Naphthalene *
	Cis-1,3-Dichloropropane	4-Nitrophenol	Nitrobenzene
	Ethyl Benzene	4,6-Dinitro-O-Cresol	Pentachlorophenol
	Methylene Chloride	Acenaphthene *	Phenanthrene *
	Styrene	Acenaphthylene *	Phenol
	Tetrachloroethylene	Aniline	Pyrene *
	Toluene	Anthracene *	
	Total Xylenes	Benzidine	
	Trans-1,3-Dichloropropene	Benzoic Acid	
	Trichlorofluoromethane	Benzo(a)anthracene *	
	Vinyl Acetate	Benzo(a)pyrene *	
	Vinylchloride	Benzo(b)fluoranthene *	
		Benzo(g,h,i)perylene *	
		Benzo(k)fluoranthene *	

* Polynuclear Aromatic Hydrocarbons (PAHs)
† Polychlorinated Biphenyls (PCBs)

APPENDIX B

RAW DATA TABLES OF PARAMETERS

TABLE B-1. 2006 Conventionals, Bacteria, and Viruses from West Point Biosolids

CONVENTIONALS

Sample No.	Date	Organic-N (mg/kg dry)	NH3-N (mg/kg dry)	Total P (mg/kg dry)	Total K (mg/kg dry)	Total Vol. Solids (%)	Tot. Solids %	pH	Total Sulfur (mg/kg dry)
L37873-1	30-Jan-06	33,300	6,990	21,100	2,000	55.9	28.6	8.97	9,550
L38073-1	13-Feb-06	34,000	6,800	13,700	1,900	54.3	30	8.90	9,800
L38353-1	13-Mar-06	52,500	5,850	19,800	2,000	58.9	28.2	9.04	10,700
L38723-1	17-Apr-06	55,100	10,000	18,900	1,900	63.2	27.2	8.98	11,000
L39049-1	15-May-06	62,100	10,000	25,400	1,800	65.9	26.1	8.45	12,700
L39464-1	19-Jun-06	53,300	9,820	17,700	1,700	65.7	27.4	8.93	12,000
L39740-1	17-Jul-06	53,400	10,500	22,900	1,400	66	23.8	9.09	12,100
L39922-1	7-Aug-06	62,800	8,410	21,300	1,400	67.8	23.9	8.93	11,600
L40296-1	18-Sep-06	51,400	9,250	20,500	1,500	69	25.5	8.73	11,600
L40687-1	16-Oct-06	48,800	9,730	19,800	1,500	70.3	25.6	9.01	12,700
L41020-1	13-Nov-06	48,500	7,650	19,700	1,700	64.2	26	8.92	11,400
L41266-1	11-Dec-06	46,500	7,450	15,400	1,600	58.9	28.2	8.96	10,400

		BACTERIA (org/100g wet)			**VIRUSES**	**PARASITES**
Sample No.	Date	Fecal-Coliform	Enterococcus	Salmonella	(PFU/100g wet)	(no units)
L37873-1	30-Jan-06	1,700,000	13,000,000	2	<2	NF
L38073-1	13-Feb-06	1,700,000	1,700,000	11	NA	NA
L38353-1	13-Mar-06	5,000,000	5,000,000	4	NA	NA
L38723-1	17-Apr-06	3,000,000	13,000,000	4	<2	NF
L39049-1	15-May-06	500,000	5,000,000	<2	NA	NA
L39464-1	19-Jun-06	800,000	5,000,000	2	NA	NA
L39740-1	17-Jul-06	13,000,000	7,000,000	4	<2	NF
L39922-1	7-Aug-06	7,000,000	3,000,000	<2	NA	NA
L40296-1	18-Sep-06	700,000	3,000,000	7	NA	NA
L40687-1	16-Oct-06	230,000	3,000,000	500	NA	NA
L41020-1	13-Nov-06	800,000	1,700,000	<2	2	NF
L41266-1	11-Dec-06	500,000	5,000,000	2	NA	NA

PFU = plaque forming units NA=not analyzed NF=none found
Viruses designate total enteric viruses such as: polioviruses, Coxsackie viruses, ECHOvirus
Parasites include the following but none were found: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, Toxocara and viable Helmith ova.

TABLE B-1 (con't.). 2006 Conventionals, Bacteria, and Viruses from West Point Biosolids						
		BACTERIA (org/g dry)		SALMONELLA	VIRUSES	PARASITES
Sample No.	Date	Fecal-Coliform	Enterococcus	(org/4g dry)	(PFU/4g dry)	(no units)
L34424-1	24-Jan-06	58,000	450,000	0.27	NF	NF
L34627-1	14-Feb-06	58,000	58,000	1.5	NA	NA
L34908-1	14-Mar-06	170,000	170,000	0.55	NA	NA
L35276-1	18-Apr-06	120,000	510,000	0.63	NF	NF
L35530-1	16-May-06	19,000	190,000	<0.32	NA	NA
L35829-1	20-Jun-06	32,000	200,000	0.32	NA	NA
L36140-1	18-Jul-06	560,000	300,000	0.69	NF	NF
L36292-1	15-Aug-06	300,000	130,000	<0.32	NA	NA
L36812-1	19-Sep-06	27,000	120,000	1	NA	NA
L37102-1	17-Oct-06	90,000	120,000	78	NA	NF
L37458-1	14-Nov-06	30,000	63,000	<0.32	<0.32	NA
L37707-1	12-Dec-06	18,000	180,000	0.29	NA	NA

PFU = plaque forming units NA=not analyzed NF=none found
Viruses designate total enteric viruses such as: polioviruses, Coxsackie viruses, ECHOvirus
Parasites include the following but none were found: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, Toxocara and viable Helmith ova.

TABLE B-2. 2006 Conventionals, Bacteria, and Viruses from South Plant Biosolids									
		CONVENTIONALS							
Sample No.	Date	Organic-N (mg/kg dry)	NH3-N (mg/kg dry)	Total P (mg/kg dry)	Total K (mg/kg dry)	Total Vol. Solids (%)	Tot. Solids %	pH	Total Sulfur (mg/kg dry)
L37873-2	23-Jan-06	56,600	11,300	20,200	2,600	66.7	22.8	8.60	9,390
L38073-2	20-Feb-06	57,500	9,700	26,300	2,300	65.0	22.6	8.50	9,470
L38353-2	13-Mar-06	62,200	12,400	25,600	2,600	67.6	22.2	8.60	9,770
L38723-2	17-Apr-06	54,400	12,500	22,700	2,700	69.0	22.6	8.40	10,000
L39049-2	15-May-06	55,000	15,700	16,000	2,700	70.0	22.0	8.60	11,300
L39464-2	19-Jun-06	58,700	10,700	27,500	3,100	68.6	22.3	8.47	11,300
L39740-2	17-Jul-06	83,600	10,100	24,700	2,200	68.6	22.6	8.40	11,000
L39922-2	7-Aug-06	54,000	10,700	26,500	2,700	68.1	22.6	8.60	10,000
L40296-2	18-Sep-06	54,800	13,700	24,100	2,400	69.5	21.0	8.40	11,100
L40687-2	16-Oct-06	52,500	12,300	24,200	2,600	69.0	20.0	8.30	11,500
L41020-2	13-Nov-06	48,200	13,000	28,600	2,600	66.1	21.8	*	10,800
L41266-2	11-Dec-06	50,200	13,900	23,500	2,200	66.4	21.7	8.60	10,700
		BACTERIA (org/100g wet)				**VIRUSES**		**PARASITES**	
Sample No.	Date	Fecal-Coliform	Enterococcus	Salmonella		(PFU/100g wet)		(no units)	
L37873-2	23-Jan-06	700,000	1,300,000	<2		<2		NF	
L38073-2	20-Feb-06	500,000	3,000,000	2		NA		NA	
L38353-2	13-Mar-06	3,000,000	50,000,000	11		NA		NA	
L38723-2	17-Apr-06	5,000,000	8,000,000	2		<2		NF	
L39049-2	15-May-06	700,000	3,000,000	<2		NA		NA	
L39464-2	19-Jun-06	800,000	5,000,000	<2		NA		NA	
L39740-2	17-Jul-06	2,300,000	5,000,000	<2		<2		NF	
L39922-2	7-Aug-06	900,000	17,000,000	<2		NA		NA	
L40296-2	18-Sep-06	13,000,000	13,000,000	2		NA		NA	
L40687-2	16-Oct-06	1,300,000	5,000,000	2		NA		NF	
L41020-2	13-Nov-06	2,300,000	5,000,000	<2		2		NA	
L41266-2	11-Dec-06	1,100,000	8,000,000	<2		NA		NA	

PFU = plaque forming units NA=not analyzed NF=none found

Viruses designate total enteric viruses such as: polioviruses, Coxsackie viruses, ECHOvirus

Parasites include the following but none were found: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, Toxocara and viable Helmith ova.

* Novrmber's biosolids were not tested for pH.

TABLE B-2 (con't.). 2006 Conventionals, Bacteria, and Viruses from South Plant Biosolids

		BACTERIA (org/g dry)		SALMONELLA	VIRUSES	PARASITES
Sample No.	Date	Fecal-Coliform	Enterococcus	(org/4g dry)	(PFU/4g dry)	(no units)
L34424-2	24-Jan-06	32,000	590,000	<0.36	NF	NF
L34627-2	14-Feb-06	22,000	130,000	0.35	NA	NA
L34908-2	14-Mar-06	140,000	2,300,000	2.02	NA	NA
L35276-2	18-Apr-06	220,000	350,000	0.35	NF	NF
L35530-2	16-May-06	31,000	130,000	<0.36	NA	NA
L35829-2	20-Jun-06	37,000	230,000	<0.37	NA	NA
L36140-2	18-Jul-06	110,000	230,000	<0.37	NF	NF
L36292-2	15-Aug-06	40,000	750,000	<0.35	NA	NA
L36812-2	19-Sep-06	640,000	640,000	0.39	NA	NA
L37102-2	17-Oct-06	70,000	250,000	0.41	NA	NF
L37458-2	14-Nov-06	110,000	230,000	<0.37	0.37	NA
L37707-2	12-Dec-06	52,000	380,000	<0.38	NA	NA

PFU = plaque forming units NA=not analyzed NF=none found

Viruses designate total enteric viruses such as: polioviruses, Coxsackie viruses, ECHOvirus

Parasites include the following but none were found: Ascaris lumbricoides, Coccidia, Giardia lamblia, Mite-ova, Nematodes, Taenia, Toxocara and viable Helmith ova.

TABLE B3. 2006 Trace Metals (mg/kg dry) for West Point Biosolids

Sample No.	Date	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb
L37873-1	30-Jan-06	8.15	257	0.21	13	2.90	20,200	48.6	409	22,800	131
L38073-1	13-Feb-06	8.53	265	0.23	15	3.01	20,100	49.7	407	23,400	136
L38353-1	13-Mar-06	8.05	291	0.20	16	3.58	22,600	48.6	454	22,100	133
L38723-1	17-Apr-06	6.51	265	<0.18	15	3.08	22,500	39.7	500	18,200	96.3
L39049-1	15-May-06	5.75	269	<0.19	14	3.04	24,400	36.9	559	16,500	99.6
L39464-1	19-Jun-06	7.37	258	<0.18	17	3.05	24,300	36.9	569	17,100	104
L39740-1	17-Jul-06	5.8	250	0.21	15	3.19	24,700	33.6	567	15,300	95.8
L39922-1	7-Aug-06	5.48	241	<0.21	15	2.90	24,700	31.1	736	14,400	91.6
L40296-1	18-Sep-06	6.43	226	<0.19	17	2.70	24,500	31.7	714	12,900	90.6
L40687-1	16-Oct-06	6.13	239	<0.19	15	2.96	26,600	34.5	730	13,700	106
L41020-1	13-Nov-06	7.46	235	<0.20	16	3.05	24,200	41.9	600	16,400	128
L41266-1	11-Dec-06	7.70	230	0.19	15	2.78	21,800	42.6	486	19,200	123

NA = not analyzed

TABLE B3. 2006 Trace Metals (mg/kg dry) for West Point Biosolids

Sample No.	Date	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Zn
L37873-1	30-Jan-06	6,750	1050	1.30	9.6	37.4	2,000	5.9	17.9	818
L38073-1	13-Feb-06	6,270	1170	1.20	8.6	37.3	1,940	5.7	15.9	823
L38353-1	13-Mar-06	6,490	1230	1.10	9.0	36.9	2,010	6.5	18.2	879
L38723-1	17-Apr-06	6,360	1110	1.10	9.3	28.6	1,930	6.3	20.6	864
L39049-1	15-May-06	5,900	1010	3.13	9.9	28.0	1,800	6.5	20.5	923
L39464-1	19-Jun-06	6,680	518	1.81	12.0	29.1	1,700	8.7*	23.3	942
L39740-1	17-Jul-06	5,340	371	0.97	12.1	25.6	1,400	7.6	21.1	950
L39922-1	7-Aug-06	7,030	328	1.10	12.4	24.1	1,400	7.1	19.9	1000
L40296-1	18-Sep-06	6,590	261	1.64	15.3	25.7	1,500	7.5	24.9	1020
L40687-1	16-Oct-06	6,600	276	1.30	14.0	27.1	1,500	7.0	22.7	1090
L41020-1	13-Nov-06	6,690	352	1.40	14.2	31.4	1,700	6.9	20.9	1080
L41266-1	11-Dec-06	5,920	890	1.10	11.5	33.6	1,600	6.7	17.1	918

NA = not analyzed

* Determined (using SPSS) to be unexplained outliers. These numbers are left out of all statistical calculations.

TABLE B4. 2006 Trace Metals (mg/kg dry) for South Plant Biosolids

Sample No.	Date	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb
L37873-2	23-Jan-06	5.88	228	<0.23	12	3.64	26,300	41.4	474	21,200	64
L38073-2	20-Feb-06	6.37	243	<0.23	14	5.66	27,600	42.3	473	24,600	72
L38353-2	13-Mar-06	5.36	240	<0.23	14	7.12	27,300	43.8	482	20,400	77
L38723-2	17-Apr-06	5.00	227	<0.22	13	5.88	28,900	54.4	500	18,700	54
L39049-2	15-May-06	5.59	222	<0.24	13	4.33	29,700	50	536	19,200	63
L39464-2	19-Jun-06	7.76	213	<0.22	14	3.48	30,600	38.2	520	20,300	48
L39740-2	17-Jul-06	5.88	200	0.23	14	3	28,700	32.2	558	17,700	39
L39922-2	7-Aug-06	5.75	205	<0.23	13	2.8	28,900	28.7	584	17,000	39
L40296-2	18-Sep-06	6.48	200	<0.23	14	3	32,800	36.2	524	15,800	39
L40687-2	16-Oct-06	6.05	203	<0.26	13	7.2	33,300	44.2	495	16,000	93
L41020-2	13-Nov-06	6.74	198	<0.22	14	6.28	31,600	46.8	472	16,500	71
L41266-2	11-Dec-06	7.00	209	<0.23	13	4.61	31,500	38.1	461	21,100	57

NA = not analyzed

TABLE B4. 2006 Trace Metals (mg/kg dry) for South Plant Biosolids

Sample No.	Date	Mg	Mn	Hg	Mo	Ni	K	Se	Ag	Zn
L37873-2	23-Jan-06	7,370	580*	0.96	13.9	30	2,600	6.1	12	697
L38073-2	20-Feb-06	8,810	700*	0.88	12.1	29	2,300	7.1	12.3	690
L38353-2	13-Mar-06	7,840	520	1.00	11.6	26	2,600	6.3	12.7	721
L38723-2	17-Apr-06	7,120	500	1.50	12.6	25	2,700	6.2	12.4	783
L39049-2	15-May-06	7,500	480	0.95	15.1	24	2,700	6.4	12.3	868
L39464-2	19-Jun-06	10,700	470	0.90	18.4	24	3,100	9.2	13.6	892
L39740-2	17-Jul-06	10,200	420	1.10	14.7	25	2,200	6.6	12.3	881
L39922-2	7-Aug-06	10,400	410	1.10	15.5	20	2,700	6.6	12.2	973
L40296-2	18-Sep-06	9,050	410	1.00	19.0	22	2,400	7.1	11.1	1040
L40687-2	16-Oct-06	10,100	410	1.10	16.4	31	2,600	7.5	10.7	1040
L41020-2	13-Nov-06	10,000	380	1.84	13.9	36	2,600	6.9	11.9	954
L41266-2	11-Dec-06	9,680	470	0.92	11.6	25	2,200	7.4	11.4	857

NA = not analyzed

None of these measures were determined using SPSS to be unexplained outliers. Such outliers would have been left out of statistical calculations.

APPENDIX C

WEST POINT (WPTP) TRACE METALS TREND PLOTS OF ANNUAL AVERAGE CONCENTRATIONS

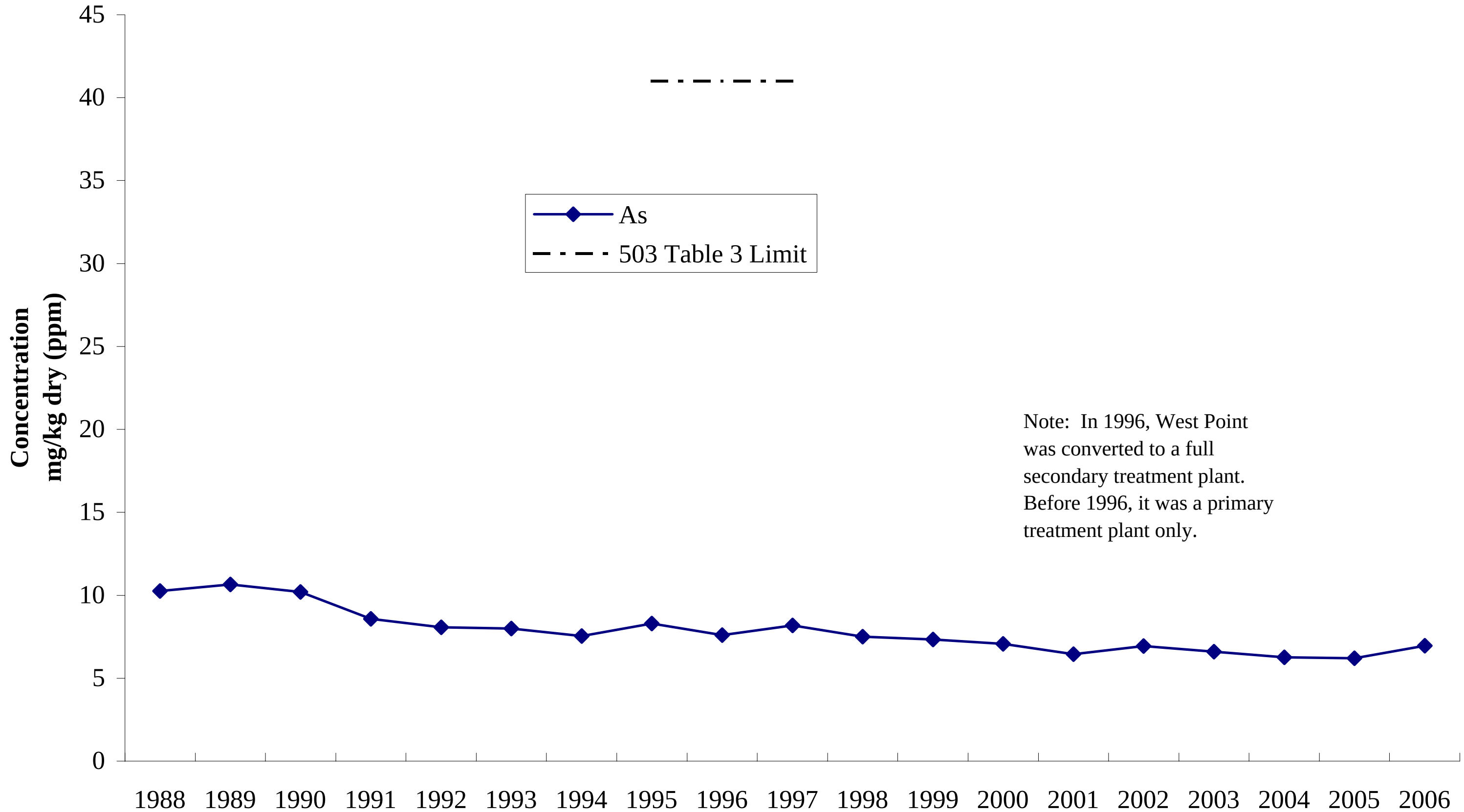

Figure C-1. Trend in Annual Average Arsenic Concentration from 1988 through 2006 for WPTP Biosolids

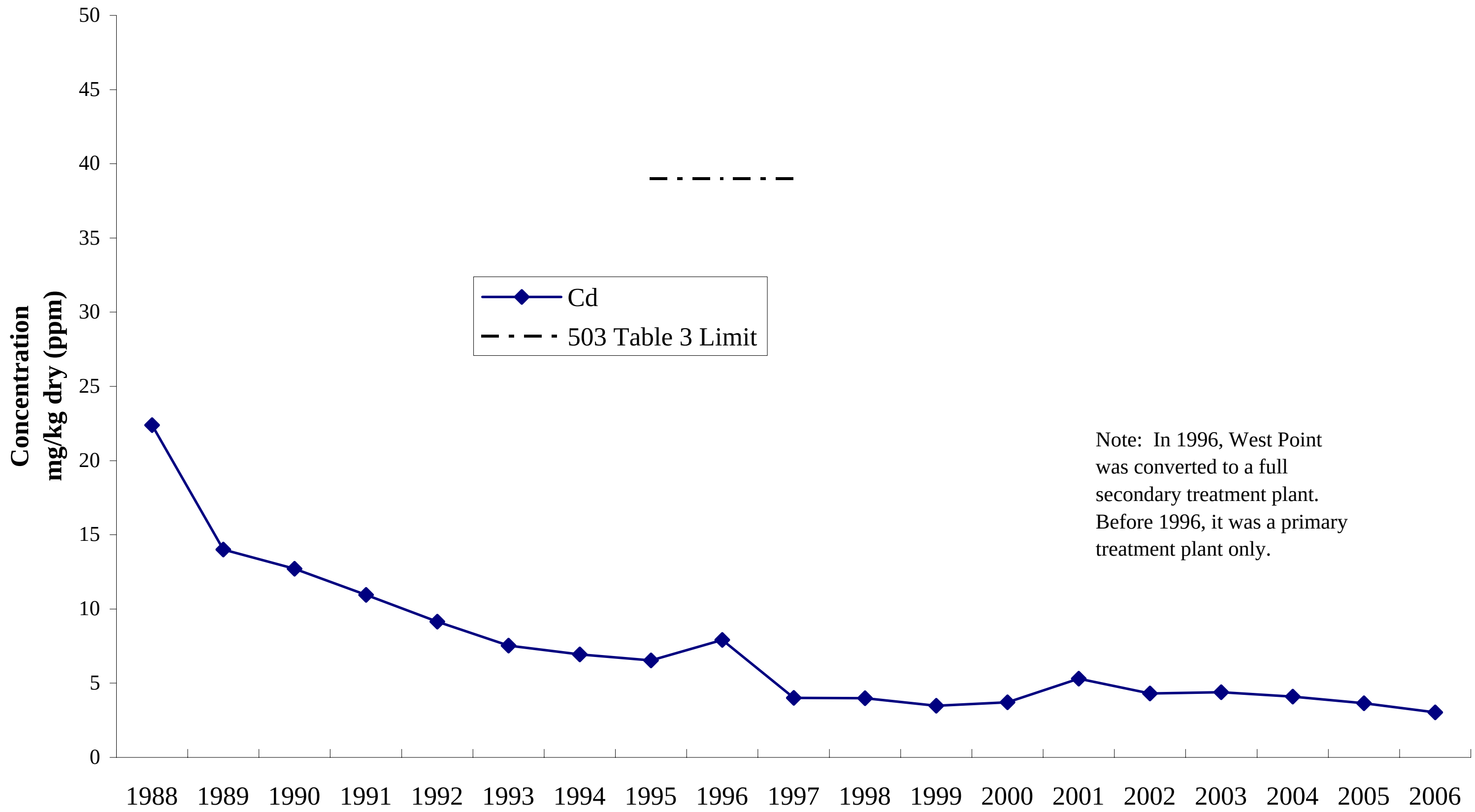

Figure C-2. Trend in Annual Average Cadmium Concentration from 1988 through 2006 for WPTP Biosolids

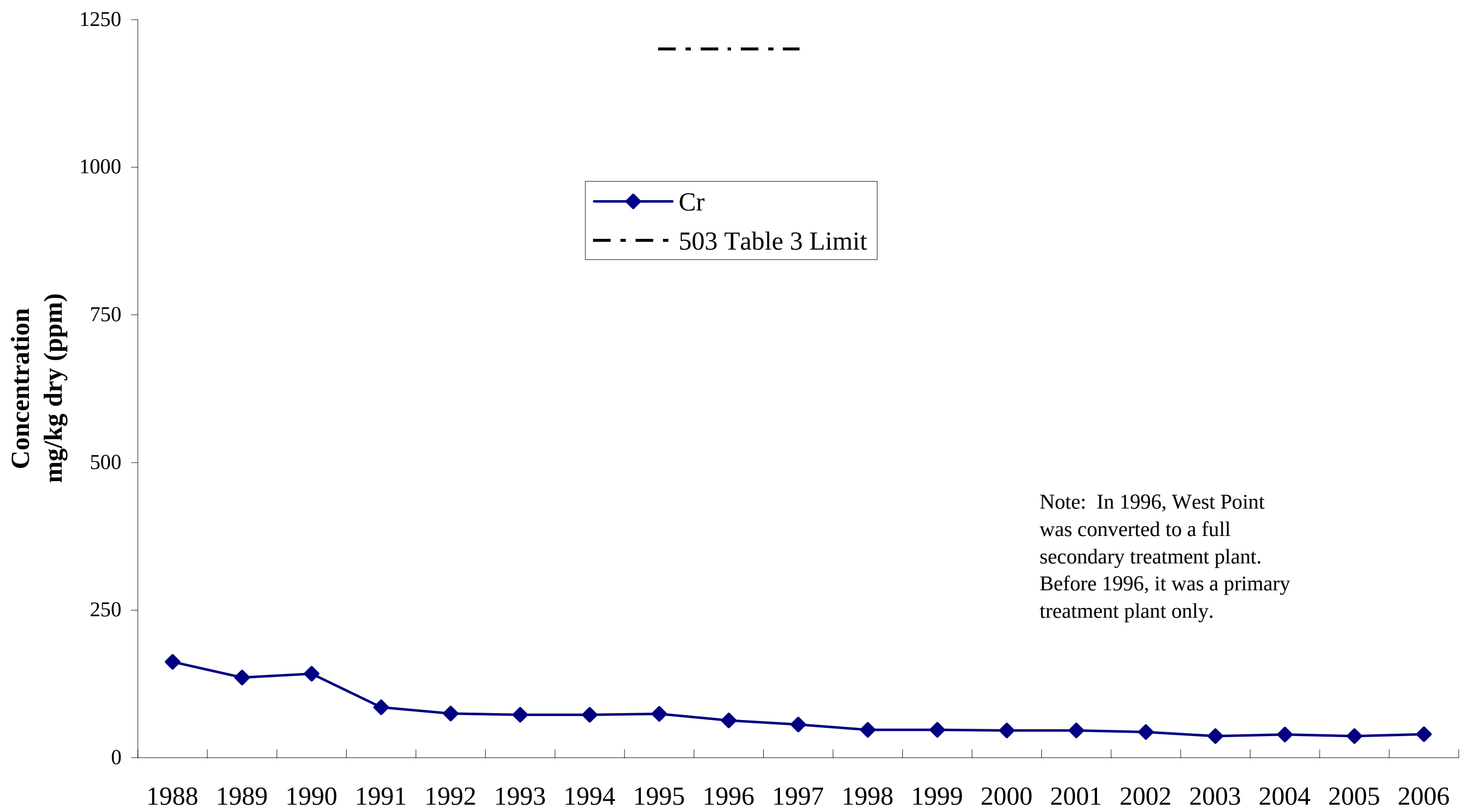

Figure C-3. Trend in Annual Average Chromium Concentration from 1988 through 2006 for WPTP Biosolids

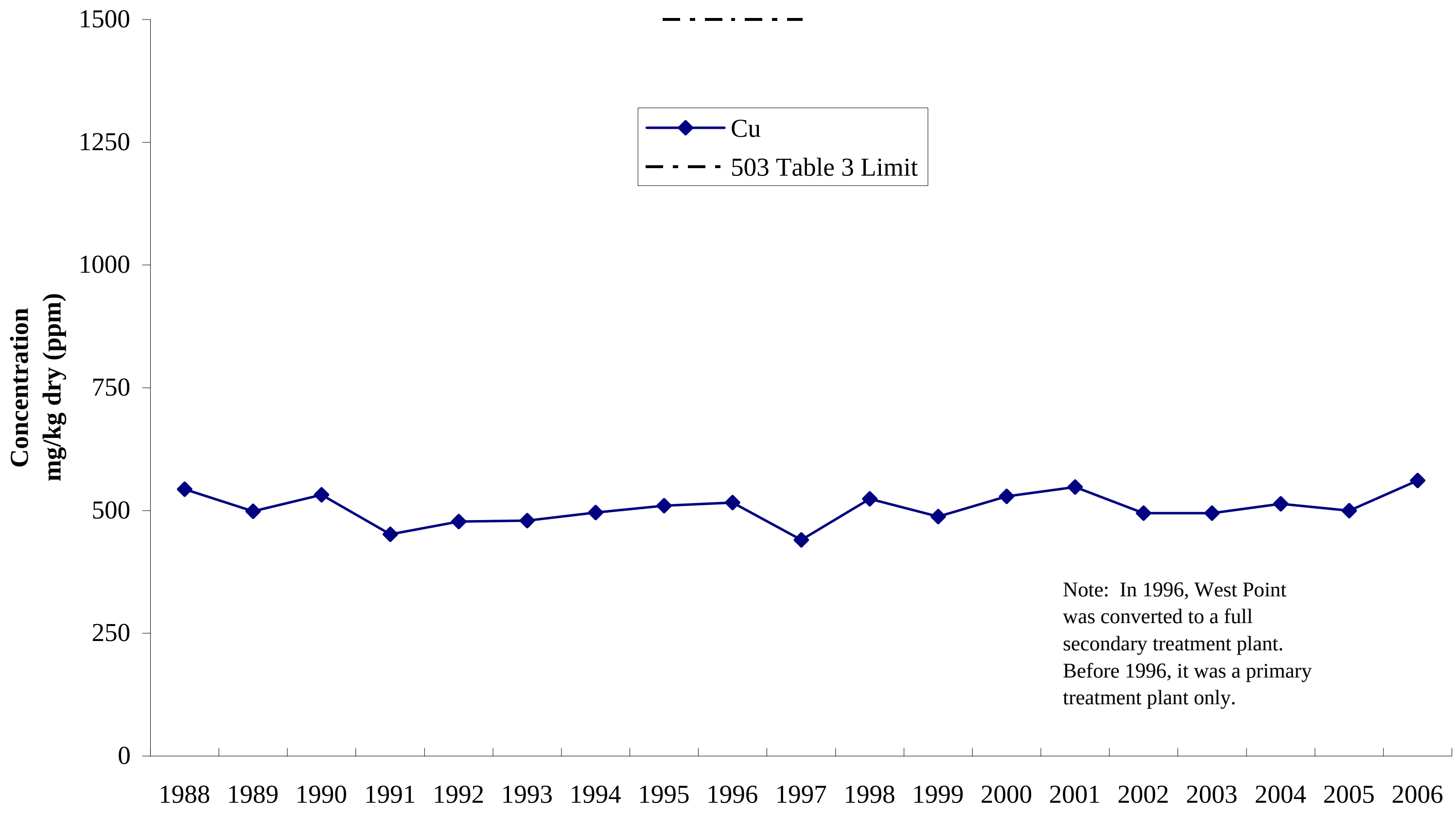

Figure C-4. Trend in Annual Average Copper Concentration from 1988 through 2006 for WPTP Biosolids

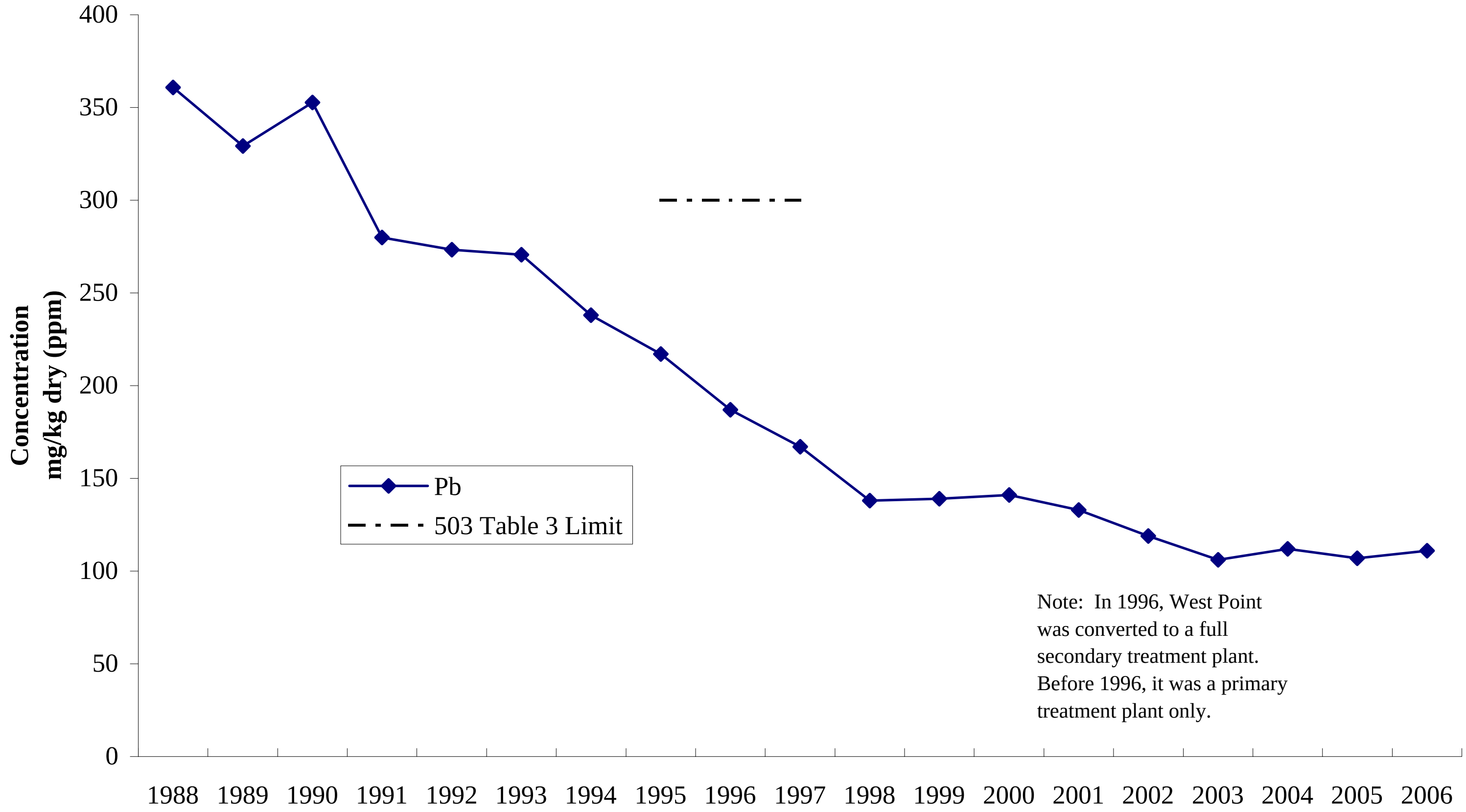

Figure C-5. Trend in Annual Average Lead Concentration from 1988 through 2006 for WPTP Biosolids

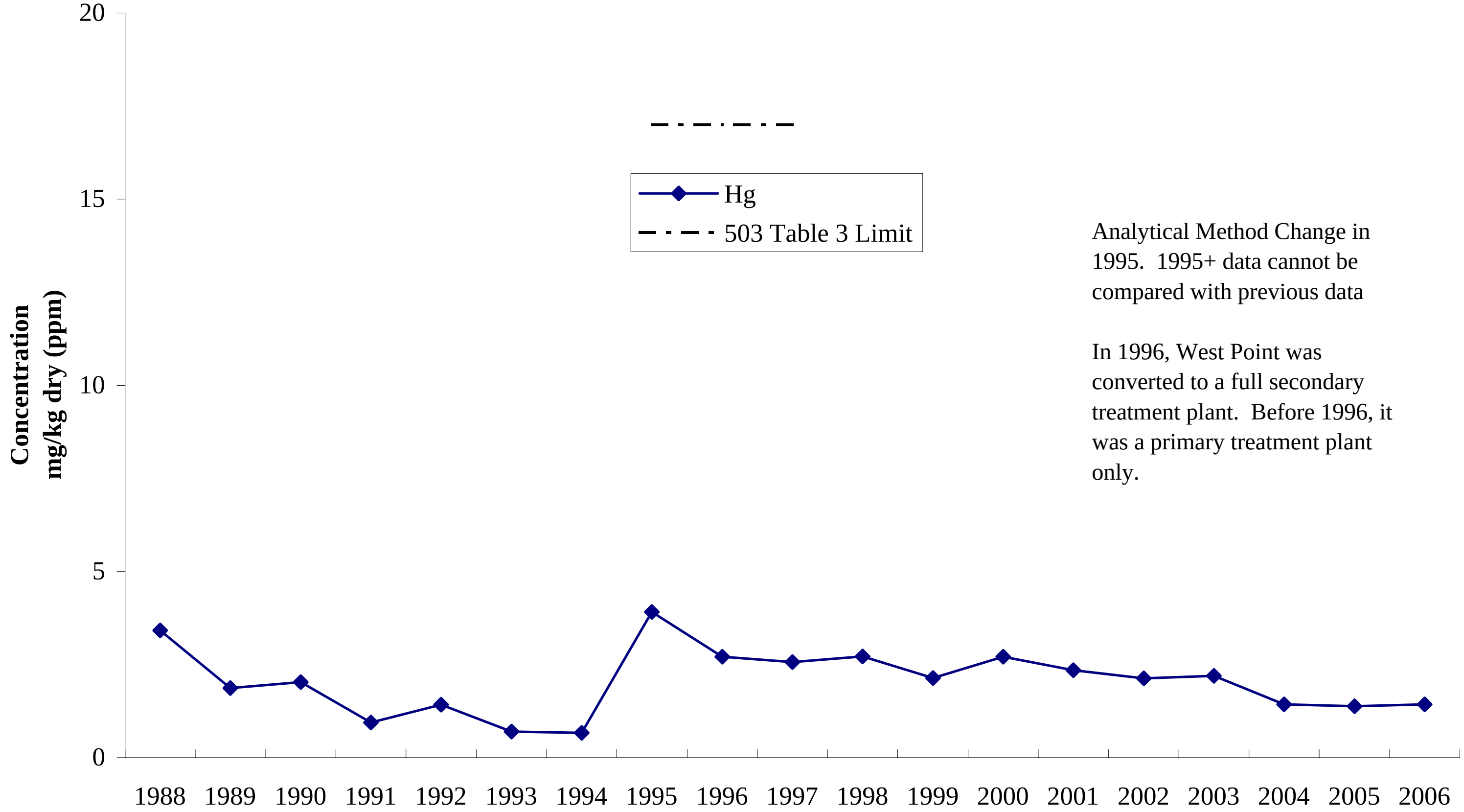

Figure C-6. Trend in Annual Average Mercury Concentration from 1988 through 2006 for WPTP Biosolids

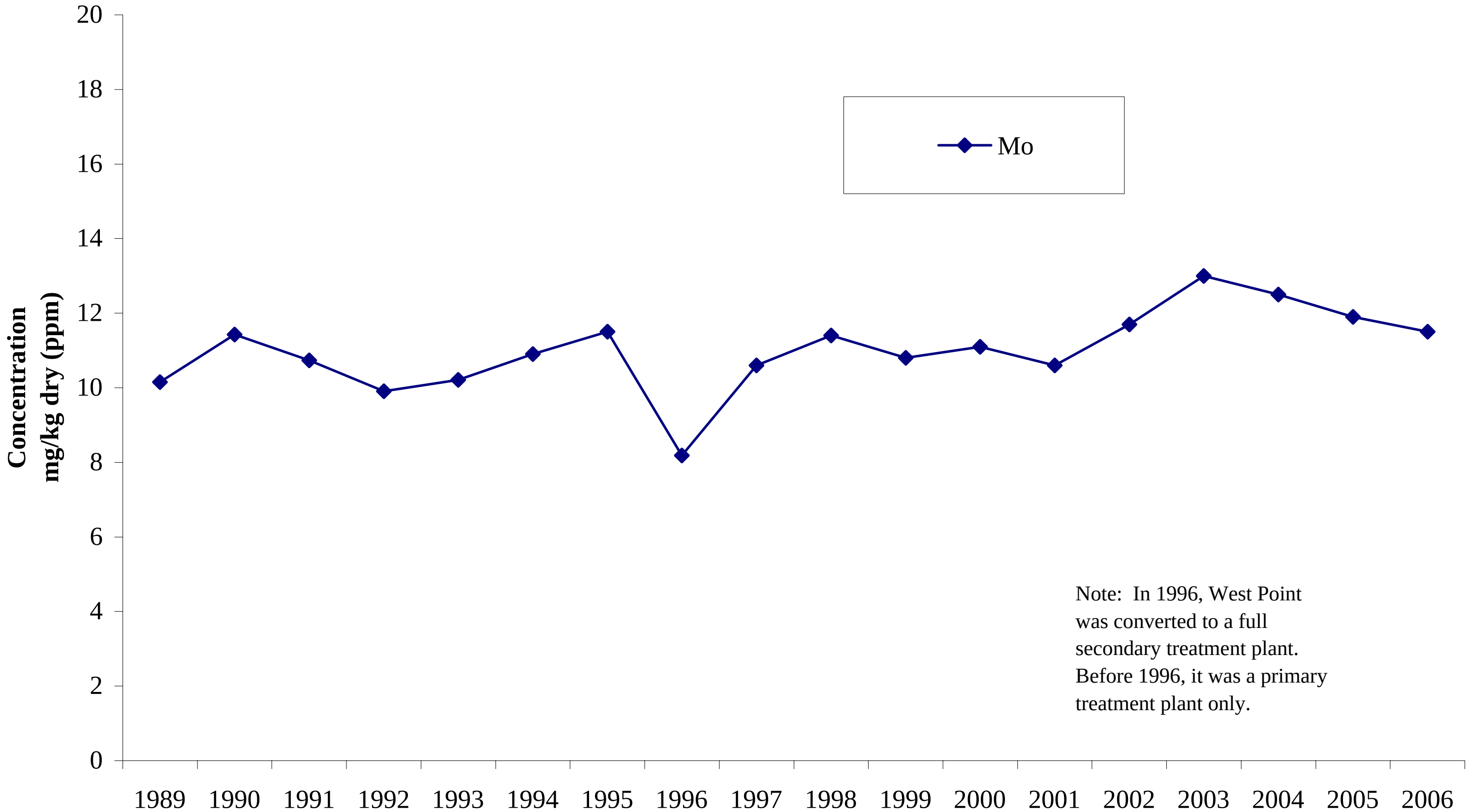

Figure C-7. Trend in Annual Average Molybdenum Concentration from 1989 through 2006 for WPTP Biosolids

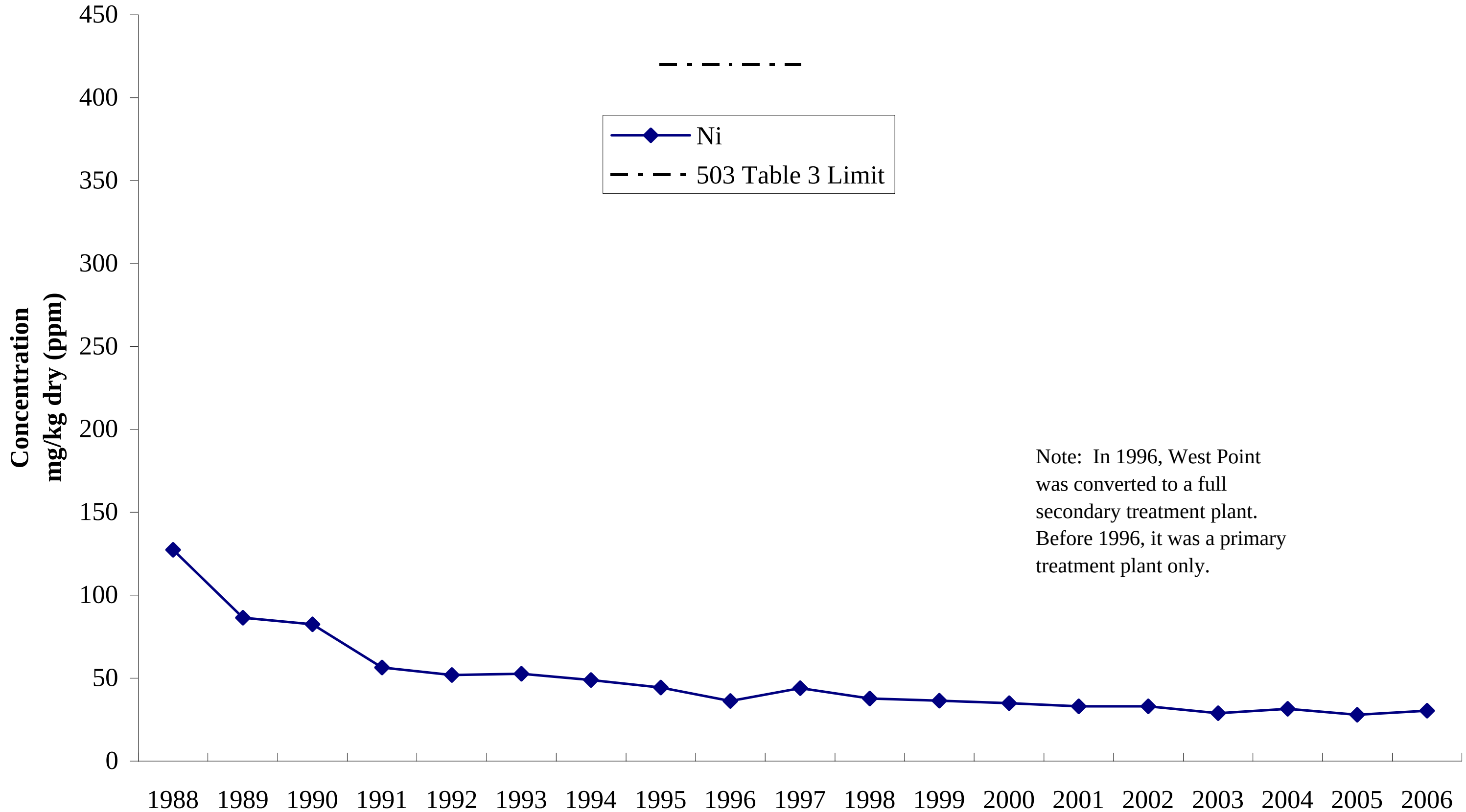

Figure C-8. Trend in Annual Average Nickel Concentration from 1988 through 2006 for WPTP Biosolids

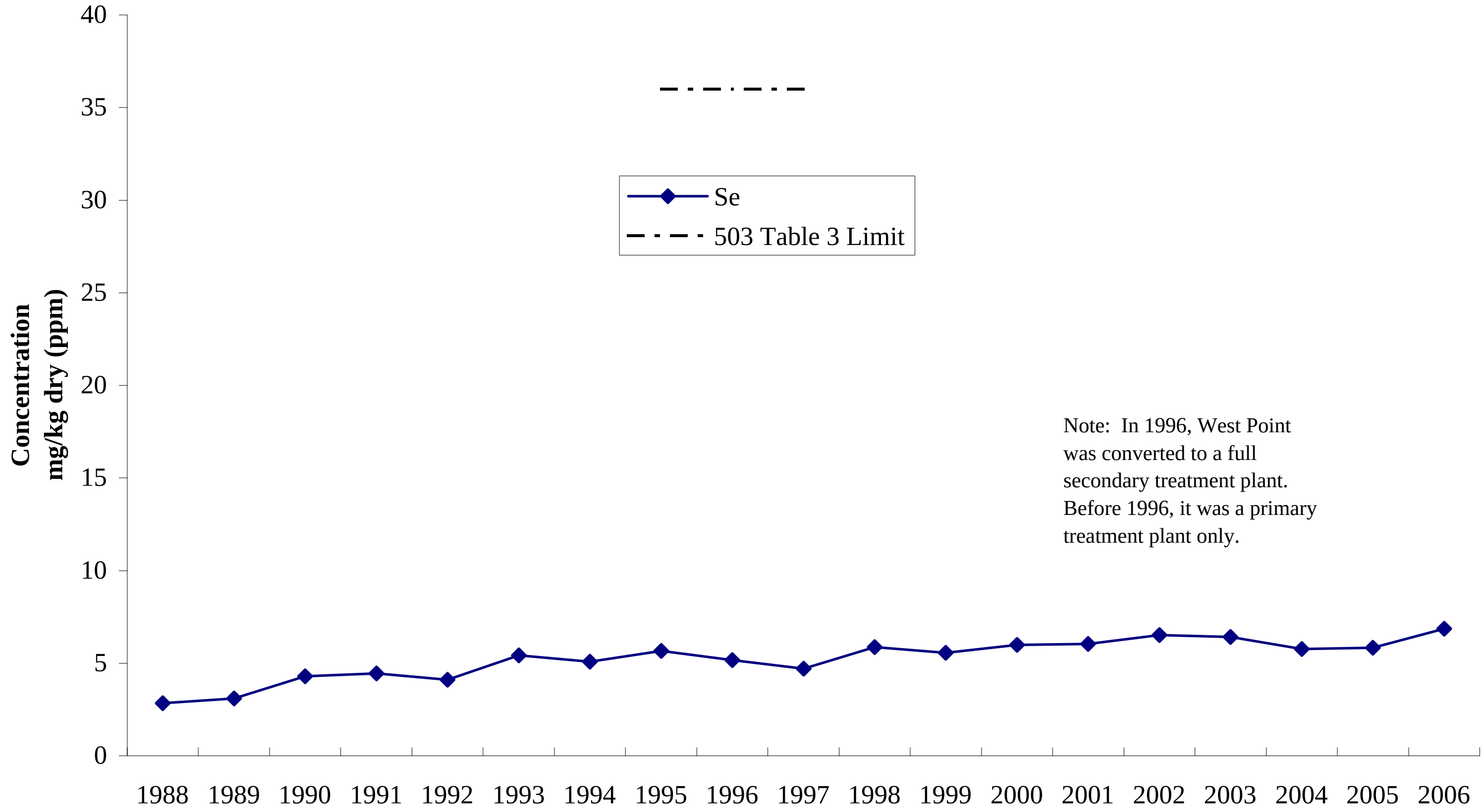

Figure C-9. Trend in Annual Average Selenium Concentration from 1988 through 2006 for WPTP Biosolids

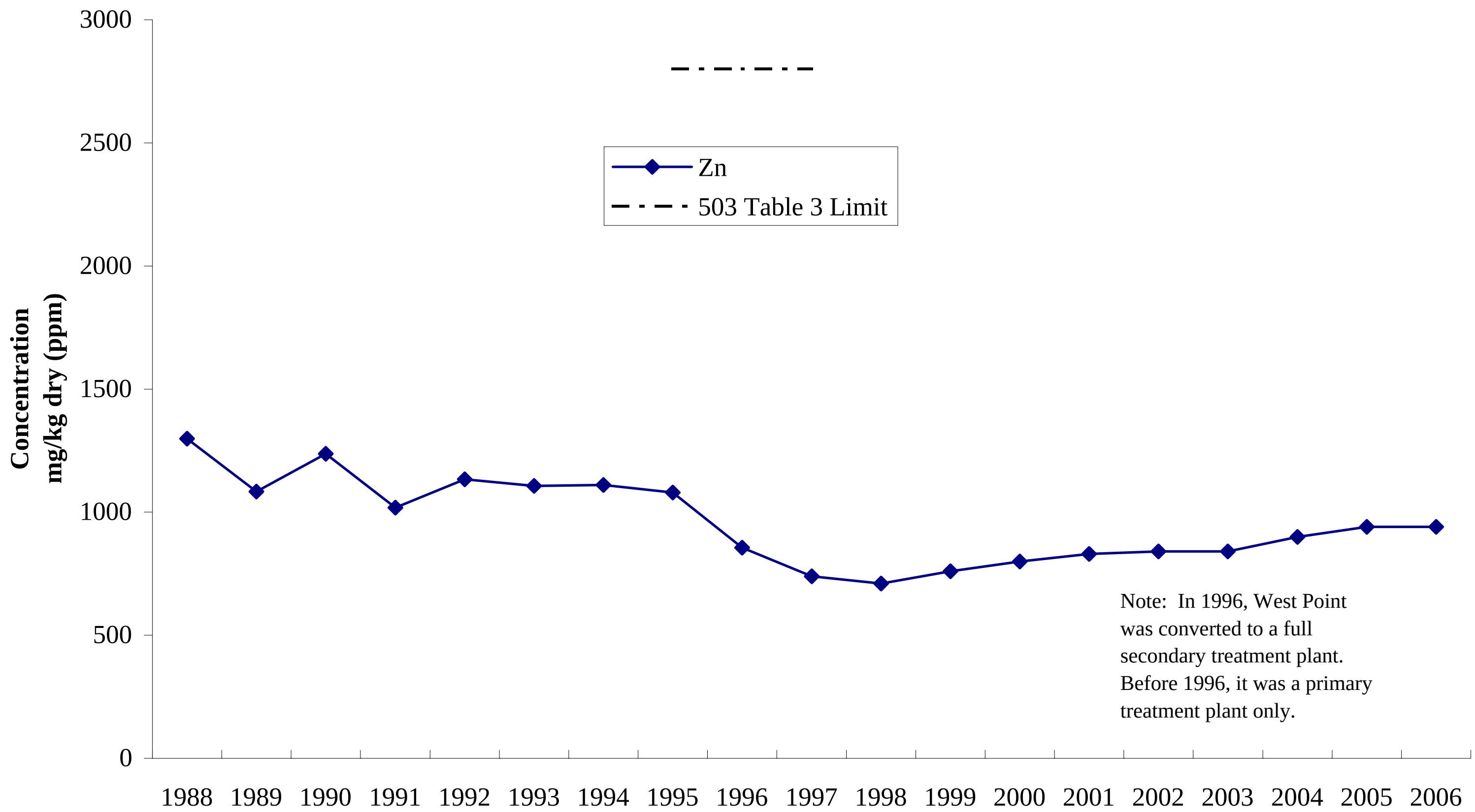

Figure C-10. Trend in Annual Average Zinc Concentration from 1988 through 2006 for WPTP Biosolids

APPENDIX D

SOUTH PLANT (STP) TRACE METALS TREND PLOTS OF ANNUAL AVERAGE CONCENTRATIONS

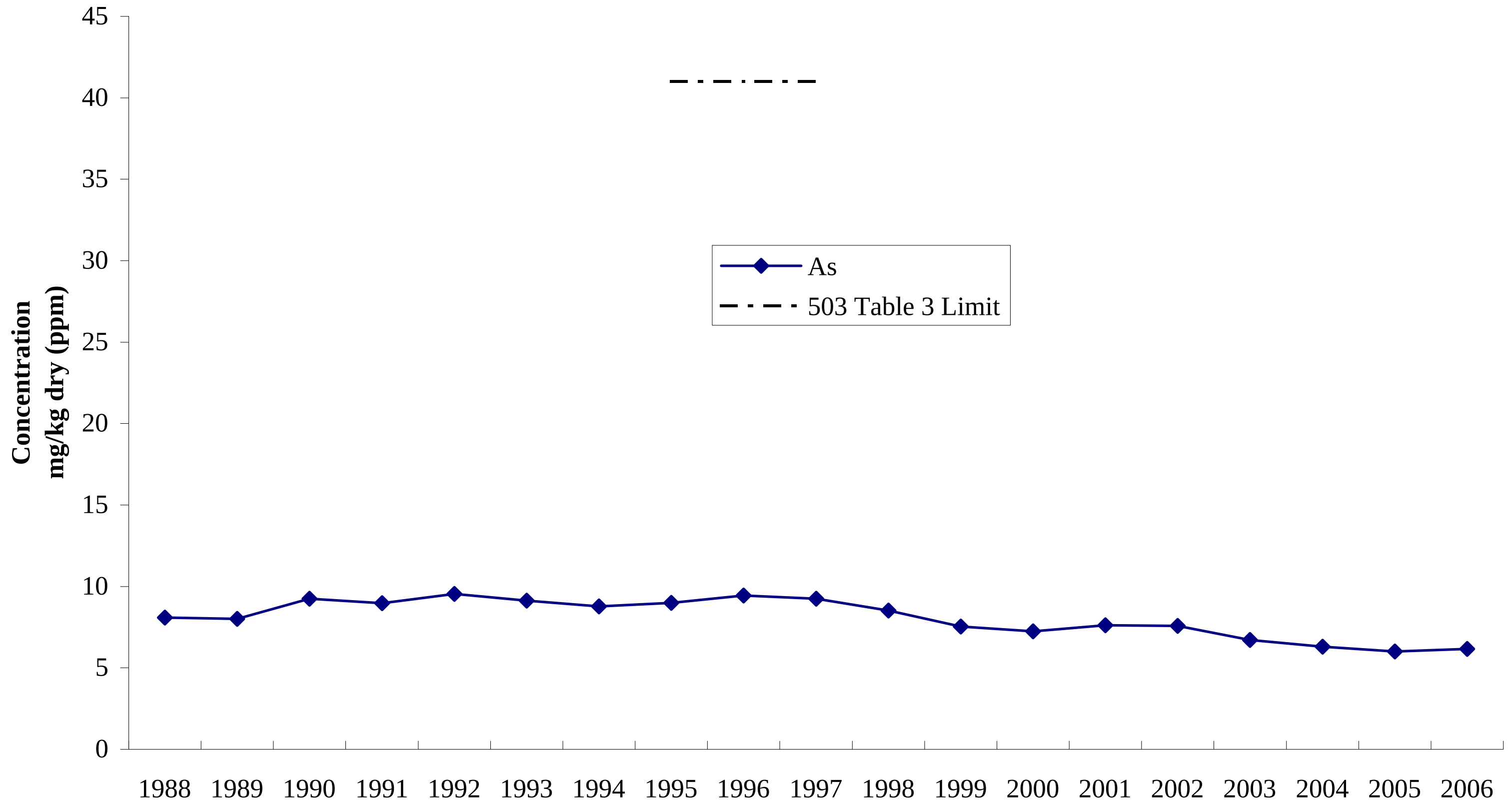

Figure D-1. Trend in Annual Average Arsenic Concentration from 1988 through 2006 for STP Biosolids

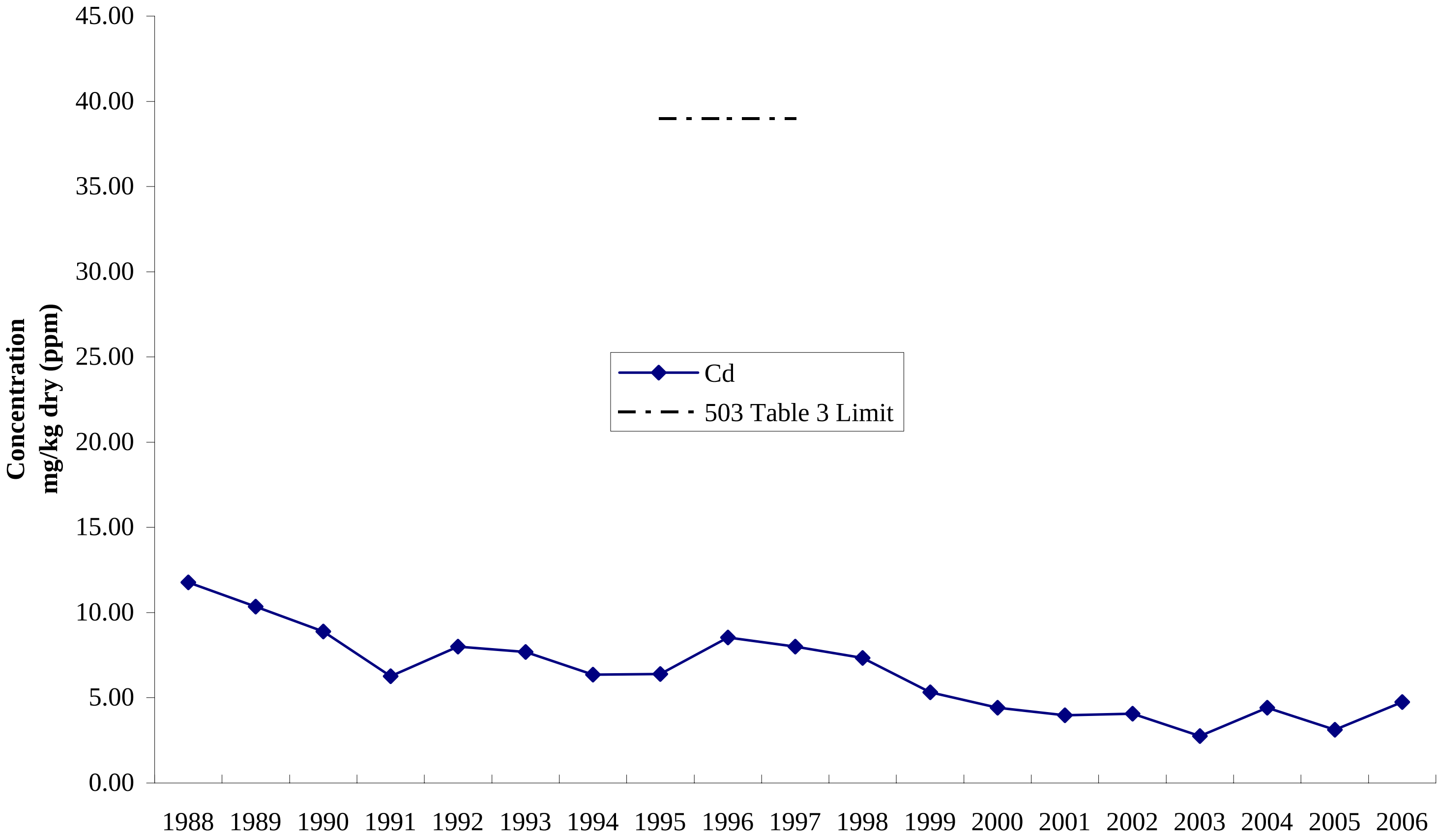

Figure D-2. Trend in Annual Average Cadmium Concentration from 1988 through 2006 for STP Biosolids

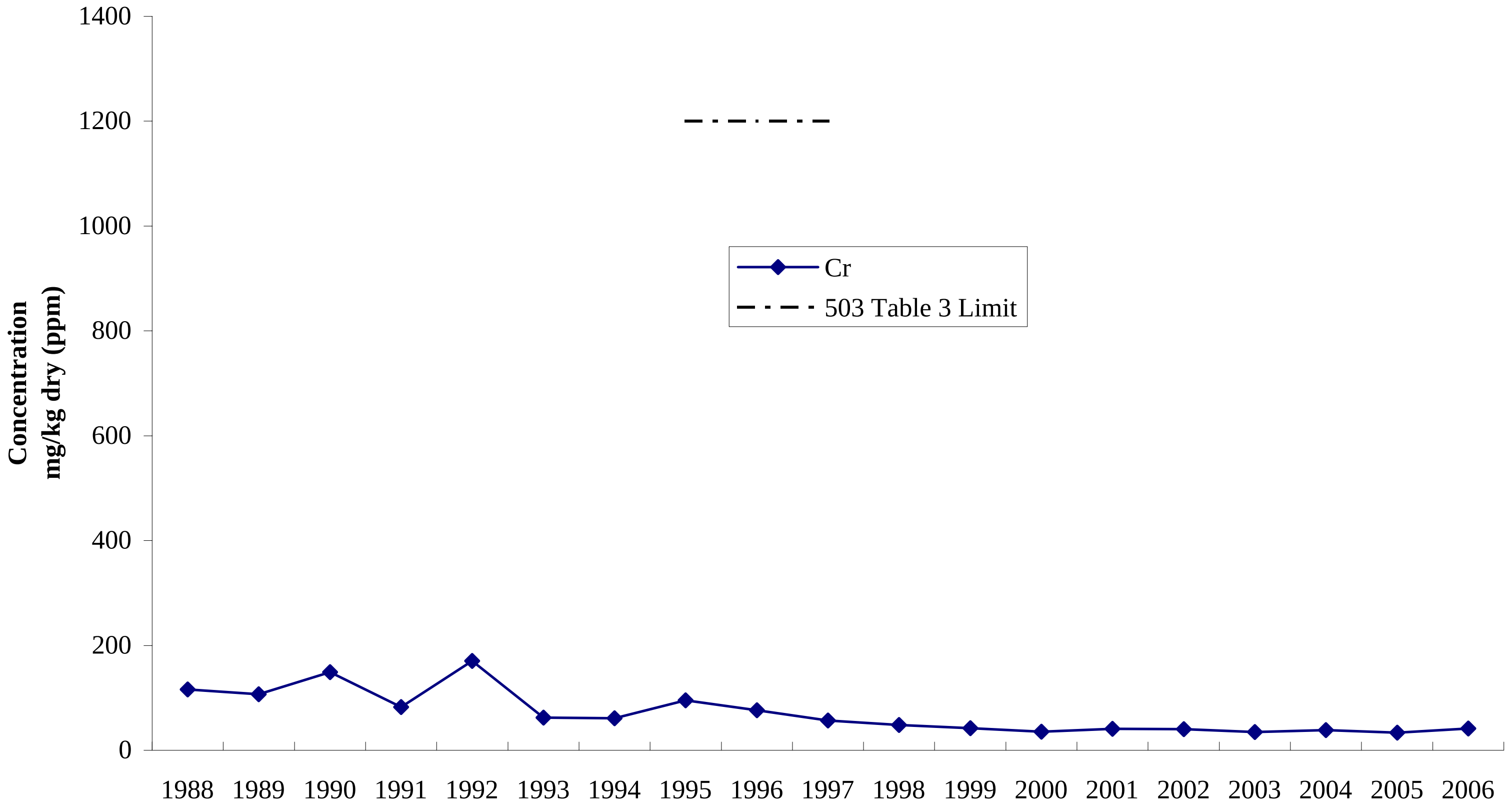

Figure D-3. Trend in Annual Average Chromium Concentration from 1988 through 2006 for STP Biosolids

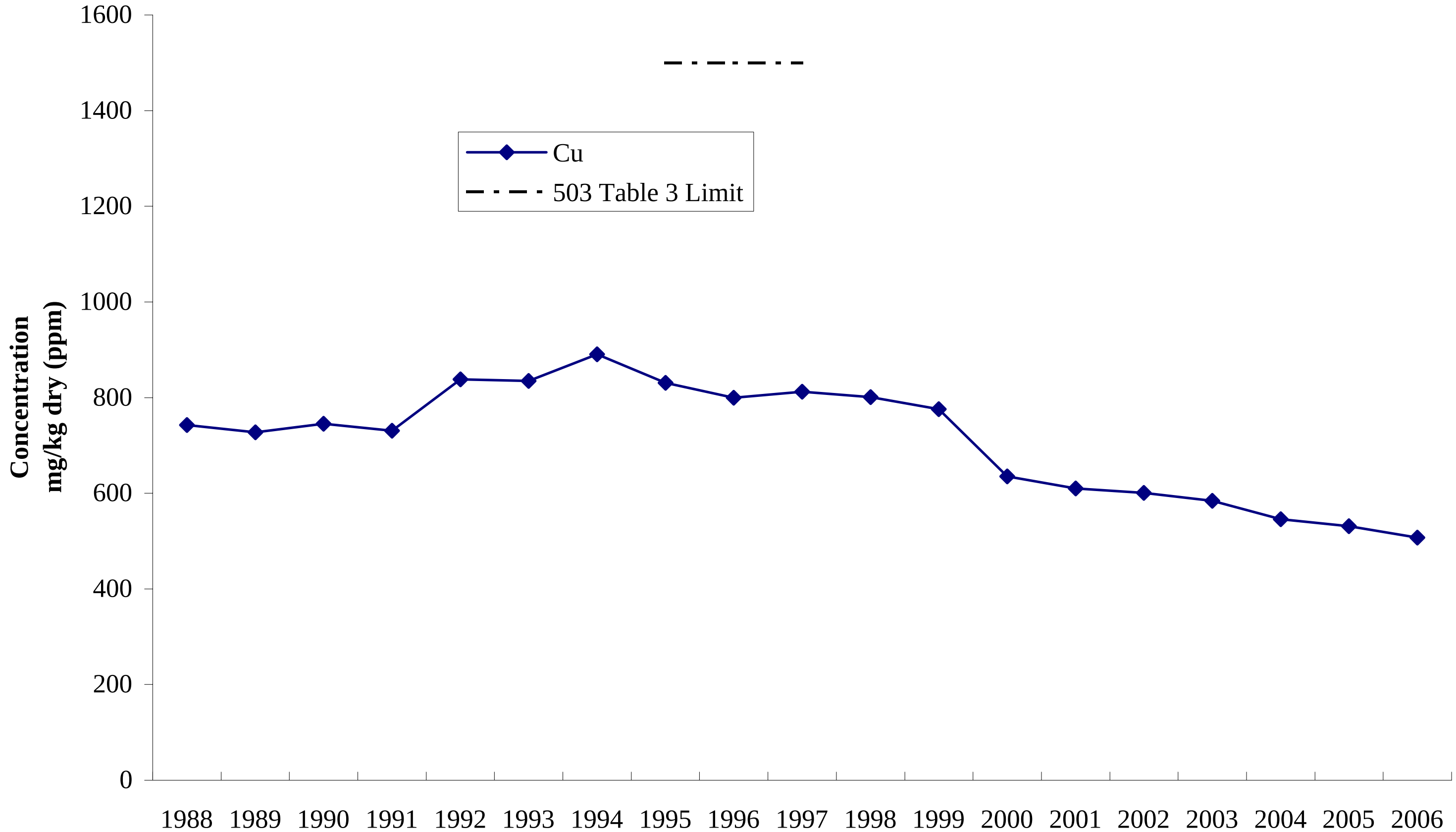

Figure D-4. Trend in Annual Average Copper Concentration from 1988 through 2006 for STP Biosolids

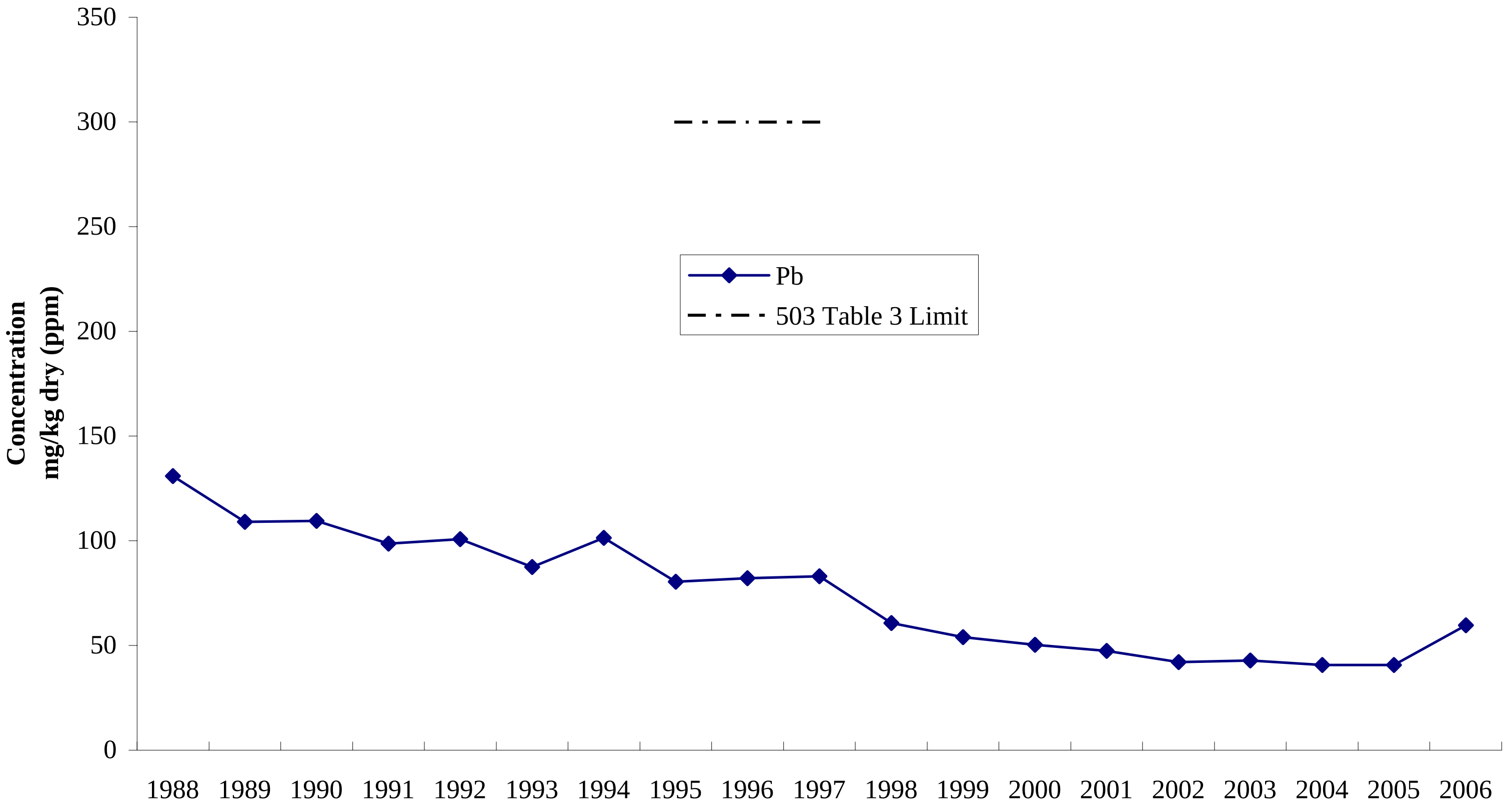

Figure D-5. Trend in Annual Average Lead Concentration from 1988 through 2006 for STP Biosolids

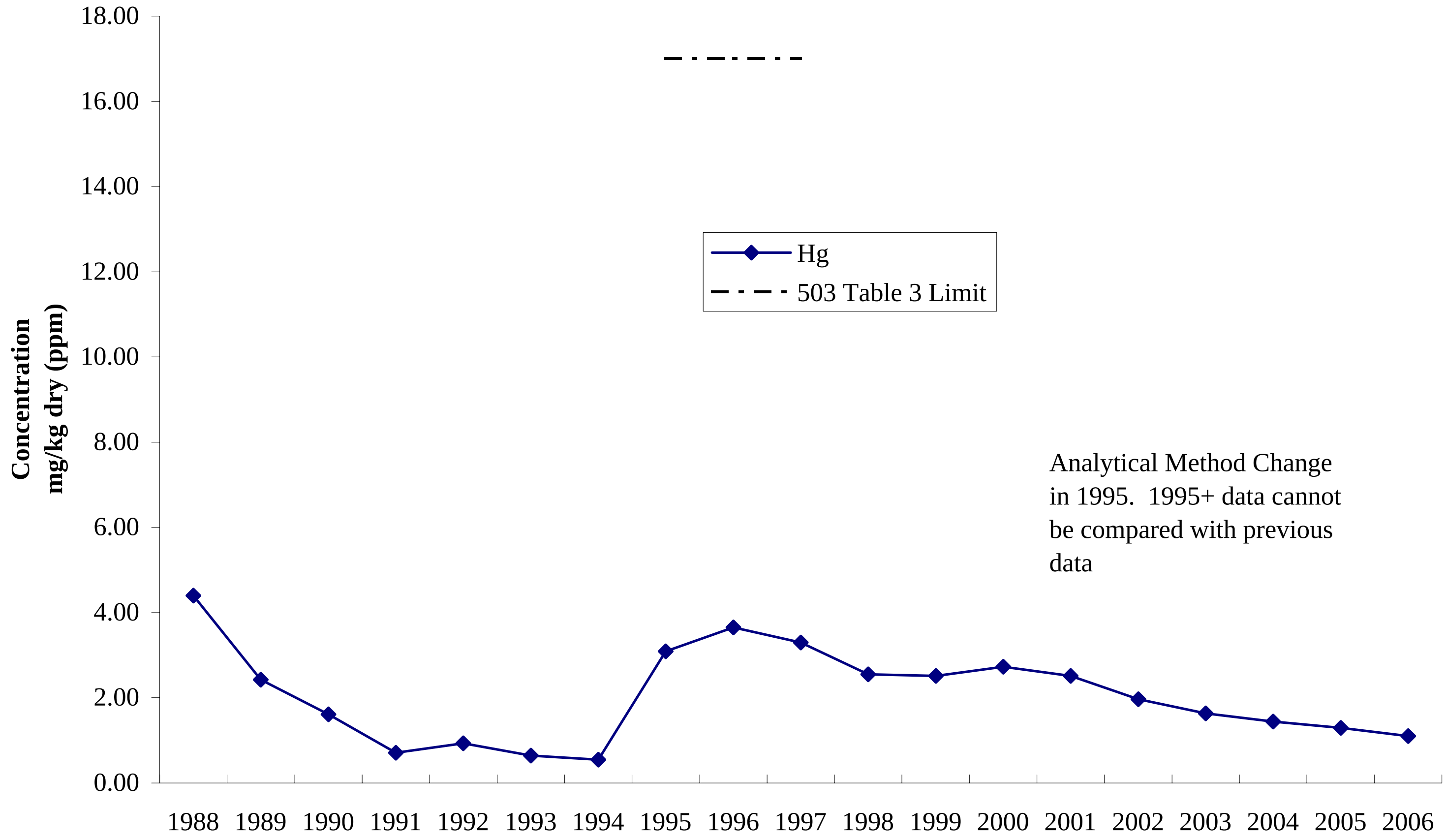

Figure D-6. Trend in Annual Average Mercury Concentration from 1988 through 2006 for STP Biosolids

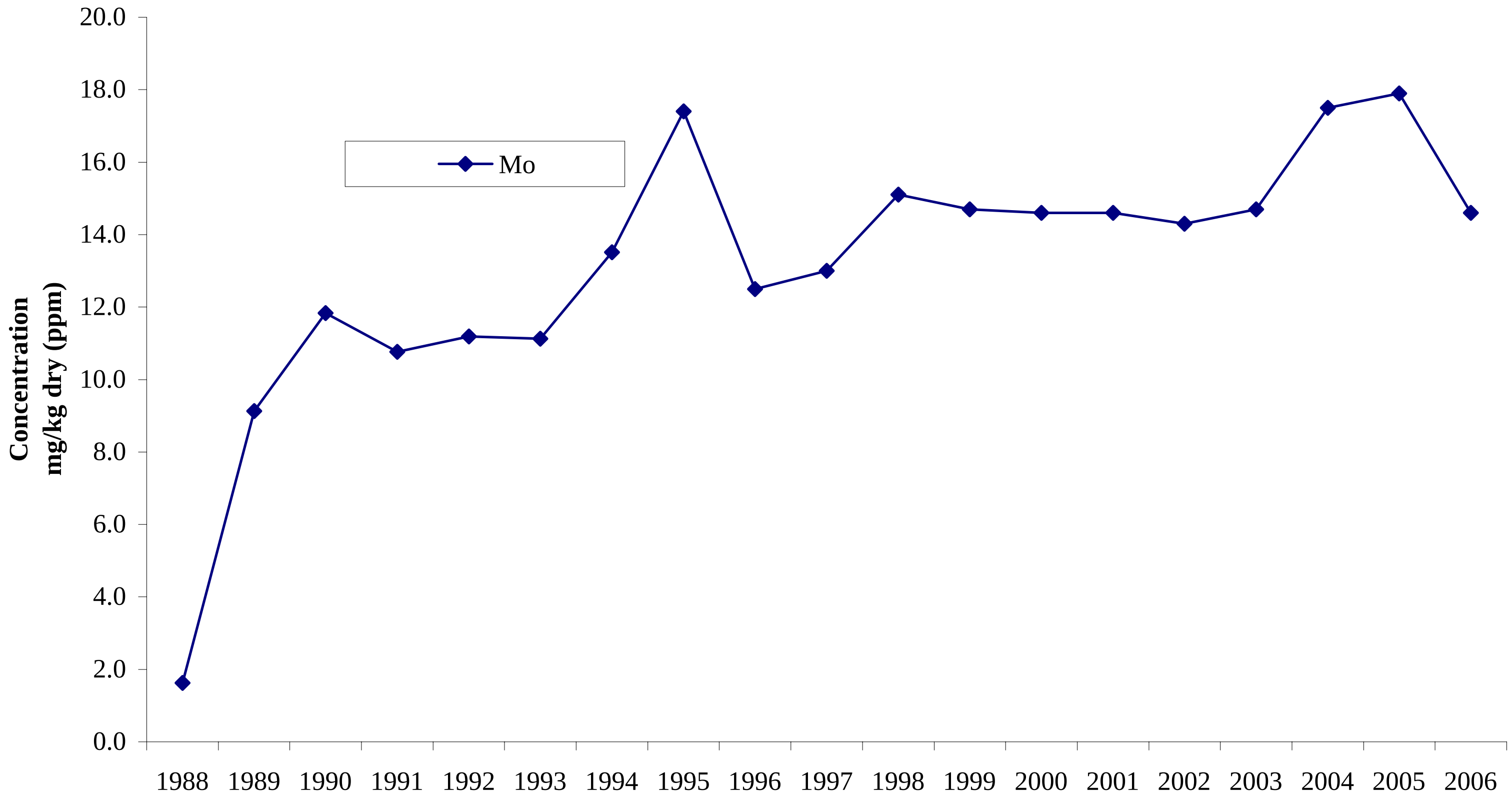

Figure D-7. Trend in Annual Average Molybdenum Concentration from 1988 through 2006 for STP Biosolids

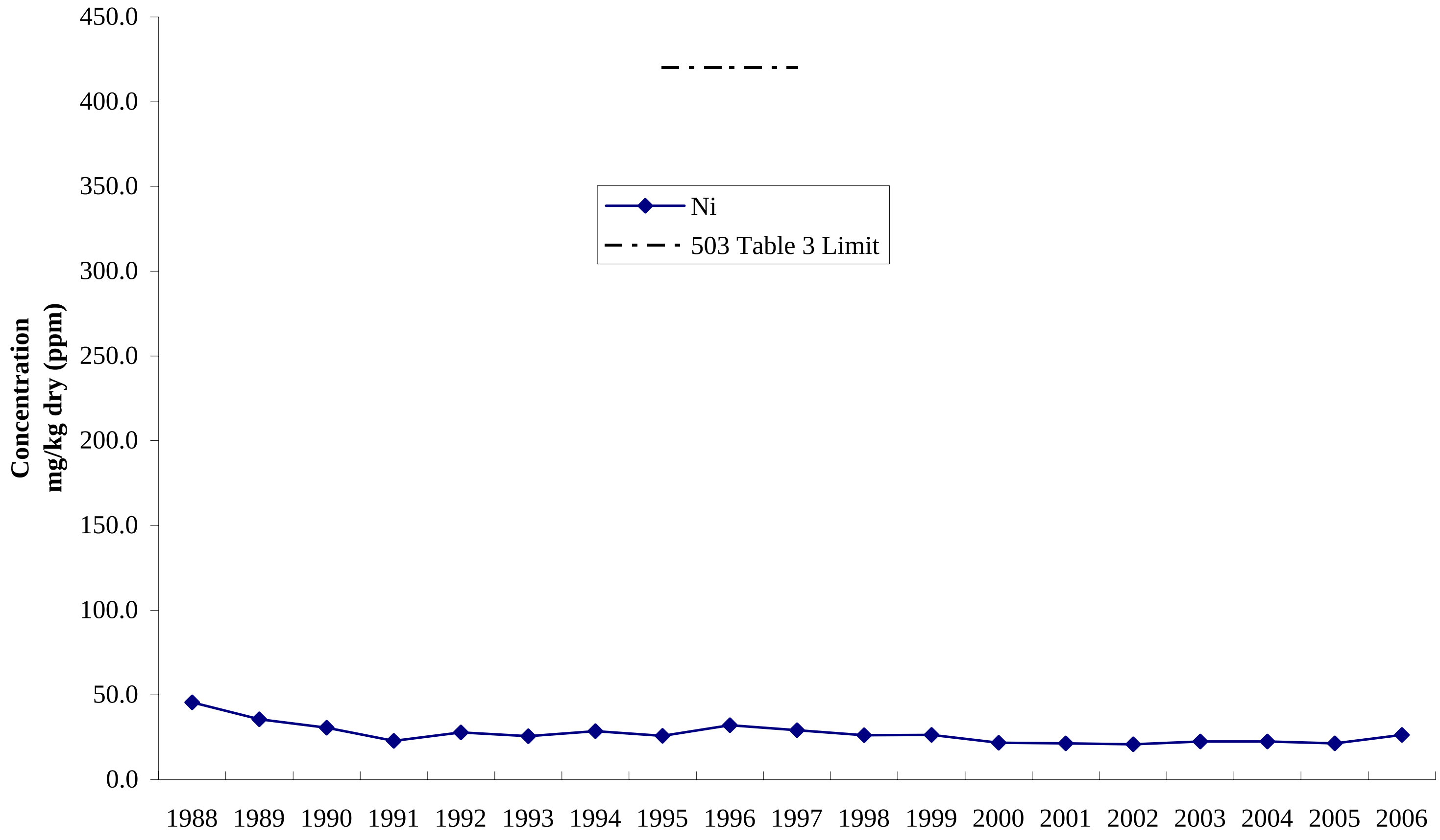

Figure D-8. Trend in Annual Average Nickel Concentration from 1988 through 2006 for STP Biosolids

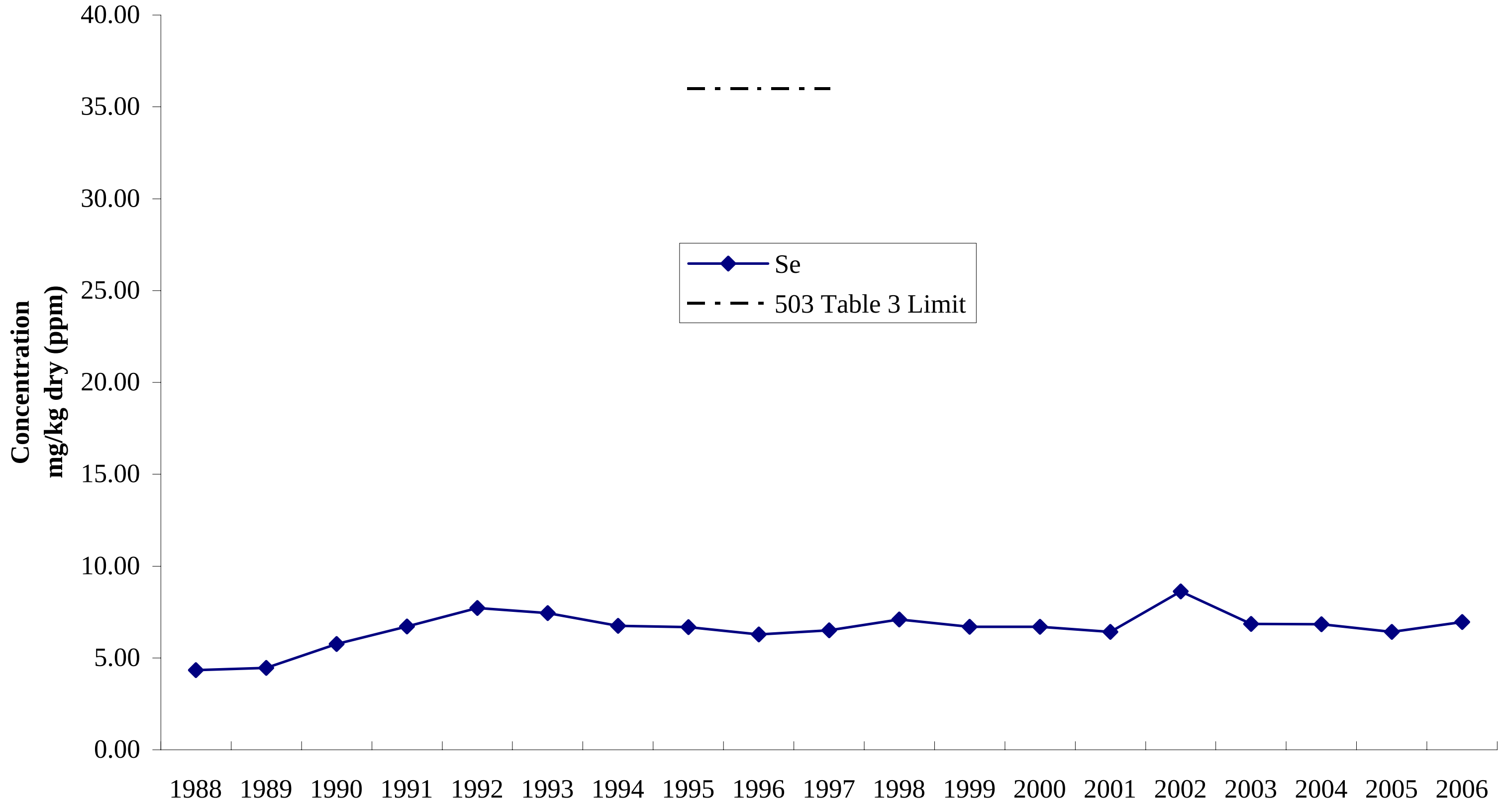

Figure D-9. Trend in Annual Average Selenium Concentration from 1988 through 2006 for STP Biosolids

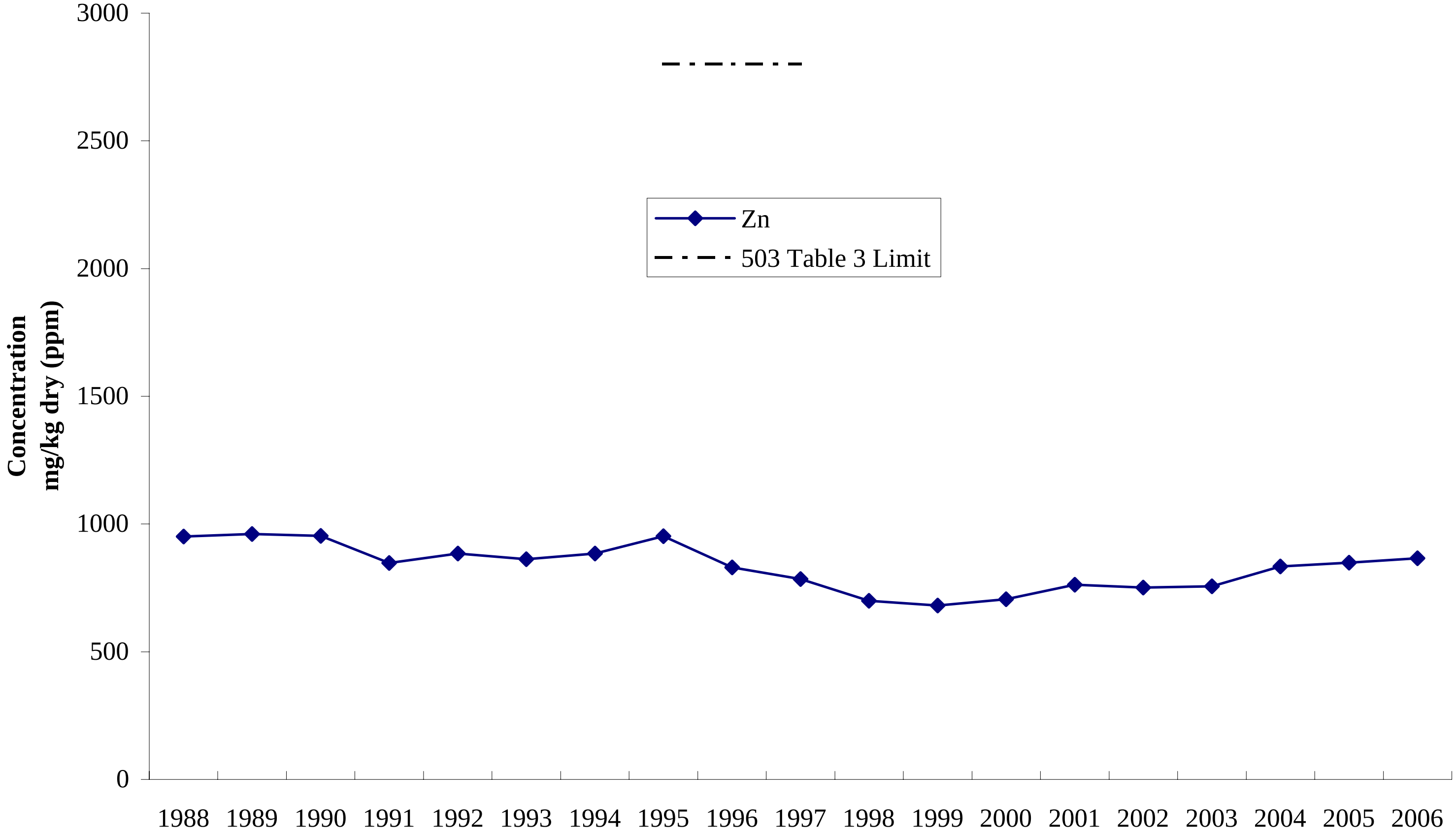

Figure D-10. Trend in Annual Average Zinc Concentration from 1988 through 2006 for STP Biosolids